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THE CENTER FOR CONSERVATION BIOLOGY
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EXECUTIVE SUMMARY

Snags (standing dead wood) are an important resource within all forest ecosystems. A prominent guild of birds within forests of North America depends upon snags for foraging, roosting and nesting. This guild includes both primary and secondary cavity nesters. A study of birds within Weyerhaeuser plantations in coastal North Carolina during the breeding seasons of 1997 and 1998 revealed a diverse community of both primary and secondary cavity nesters. Examination of patterns across the management cycle suggested that commercial thinning operations were important events that drove snag availability and the associated bird community. From a population perspective, snag availability reflects the balance between snag losses due to falling and recruitment associated with tree mortality. Understanding the population dynamics of snags and how they are influenced by management/harvest operations is essential to achieving an understanding of how pine plantations fit within the broader landscape in terms of value to wildlife species.

Studies were conducted during the spring and summer of 2002 on the Weyerhaeuser Company J&W management tract located within the coastal plain of North Carolina. Snag and bird surveys were conducted within 35 study plots consisting of 5 replicates of 7 different stand age classes. Snags were surveyed to quantify the population dynamics of snags within pine plantations and to determine how or if these snag dynamics are influenced by timber operations. Birds were surveyed to determine how the bird community responds to snag availability/dynamics.

A total of 1,186 snags were identified and characterized within the 35 study blocks. Total snag numbers peaked 1-2 years after the first commercial thin and overall snag numbers declined as the plantation stands matured. Although density was lower, snags within the older age classes were larger, had undergone more decomposition and were more likely to support cavities. Results of bird surveys showed that species richness increased with stand age and that the guild of birds the utilize snags and cavities were not frequently detected until after the first commercial thin. Commercial thinning events appear to be quite beneficial to birds that utilize snags and cavities. A side-effect of this management technique is the creation of snags that provide foraging, roosting and nesting sites for these bird species.

BACKGROUND
Context

Snags (standing dead wood) are an important resource within all forest ecosystems. A prominent guild of birds within forests of North America depends upon snags for foraging, roosting and nesting (Raphael and White, 1984). This guild includes both primary and secondary cavity nesters. Primary cavity nesters are those species such as woodpeckers and nuthatches that have the morphological adaptations to excavate their own cavities. Secondary cavity nesters are those species such as the Eastern Bluebird and Tufted Titmouse that do not typically excavate their own cavities but instead utilize natural cavities or those excavated and abandoned by primary cavity nesters. A widely held view within the ornithological and land management communities is that pine plantations do not support primary and secondary cavity users due to the limitation of snags. Snags numbers are generally kept to a minimum in managed pine plantation because they are not desirable for production of wood products and they may pose a safety hazard (Gunn and Hagan, 2000)

A study of birds within Weyerhaeuser plantations in coastal North Carolina during the breeding seasons of 1997 and 1998 revealed a diverse community of both primary and secondary cavity nesters. Examination of patterns across the management cycle suggested that commercial thinning operations were important events that drove snag availability and the associated bird community. An assessment of habitat use by Brown-headed Nuthatches suggested that commercial thinning events were important for both creating snags and reducing interference for their use by understory vegetation.

From a population perspective, snag availability reflects the balance between snag losses due to falling and recruitment associated with tree mortality (Morrison and Raphael, 1993). Understanding the population dynamics of snags and how they are influenced by management/harvest operations is essential to achieving an understanding of how pine plantations fit within the broader landscape in terms of value to wildlife species. State of decay, size class, understory conditions, and other factors are also important in whether or not snags are useable to specific bird species. Understanding species-specific requirements will help to explain why certain species enter the plantation bird community at different times during the management cycle.

Objectives

This study has four interrelated objectives including (1) to quantify the population dynamics of snags within pine plantations, (2) to determine how or if these snag dynamics are influenced by timber operations, (3) to determine how the bird community responds to snag availability/dynamics, and (4) to quantify the characteristics of snags that are required by the various user species.

METHODS

Study Area

This study was conducted entirely on the Weyerhaeuser Company J&W management tract. The J&W management tract is located on the extreme western end of the Albemarle-Pamlico Peninsula, in Beaufort, Martin, and Washington Counties, North Carolina (Figure 1). The area was originally dominated by tall pocosin and hardwood swamps before being ditched, drained and cleared for agricultural practices and other land uses, prior to acquisition by Weyerhaeuser. Presently, the majority of the J&W tract is managed as pine plantation and is surrounded by a matrix of agricultural, residential, and forested lands.

Pine plantation management activities generally occur during a 30-35 year crop rotation period. Loblolly pines (*Pinus taeda*) are planted at a relatively low density (<1,200 stems/ha), commercially thinned 1-3 times during maturation, and then harvested by clearing all pine and hardwood stems. Commercial thinning events are usually conducted approximately 10 and 20 years after planting. These thinning events create alternating strips of sheared and non-sheared lanes within the management stand. The staggered regime of planting, thinning and harvesting activities creates a matrix of different aged stands.

Study Design

Studies were conducted within 35 plots consisting of 5 replicates of 7 different stand age classes (Table 1). Age classes were chosen to represent stages throughout the management cycle and included; (1) pre-thin, approximately 10 year after planting and chopped, (2) 1-2 years after first commercial thin, (3) 3-4 years after fist thin, (4) 5-6 years after first thin, (5) 1-2 years after second thin, (6) 3-4 years after second thin, and (7) 5-6 years after second thin. Within each replicate a 9-ha block was established and within each 9-ha block a 4-ha focal block was established (Figure 2). Stands were chosen based upon ease of access, lack of dense cane understory, and exclusion from the current year's thinning and harvesting schedule.

Snag Surveys

Snags were surveyed within each 9-ha block by methodically walking each sheared or chopped lane and identifying all snags present. Snags were defined as a stem $\geq$ 1.5 m tall, with a diameter at breast height (DBH) $\geq$8 cm, with no live needles or leaves present and leaning < 35°. When a snag was encountered it was flagged, marked with a numbered aluminum tree tag attached with bailing wire, position recorded with a Garmin eTrex Legend GPS unit, and characterized. Data taken to characterize each snag included; stand number, snag number, height, DBH, number of limbs $\leq$ 1 m projecting from the main

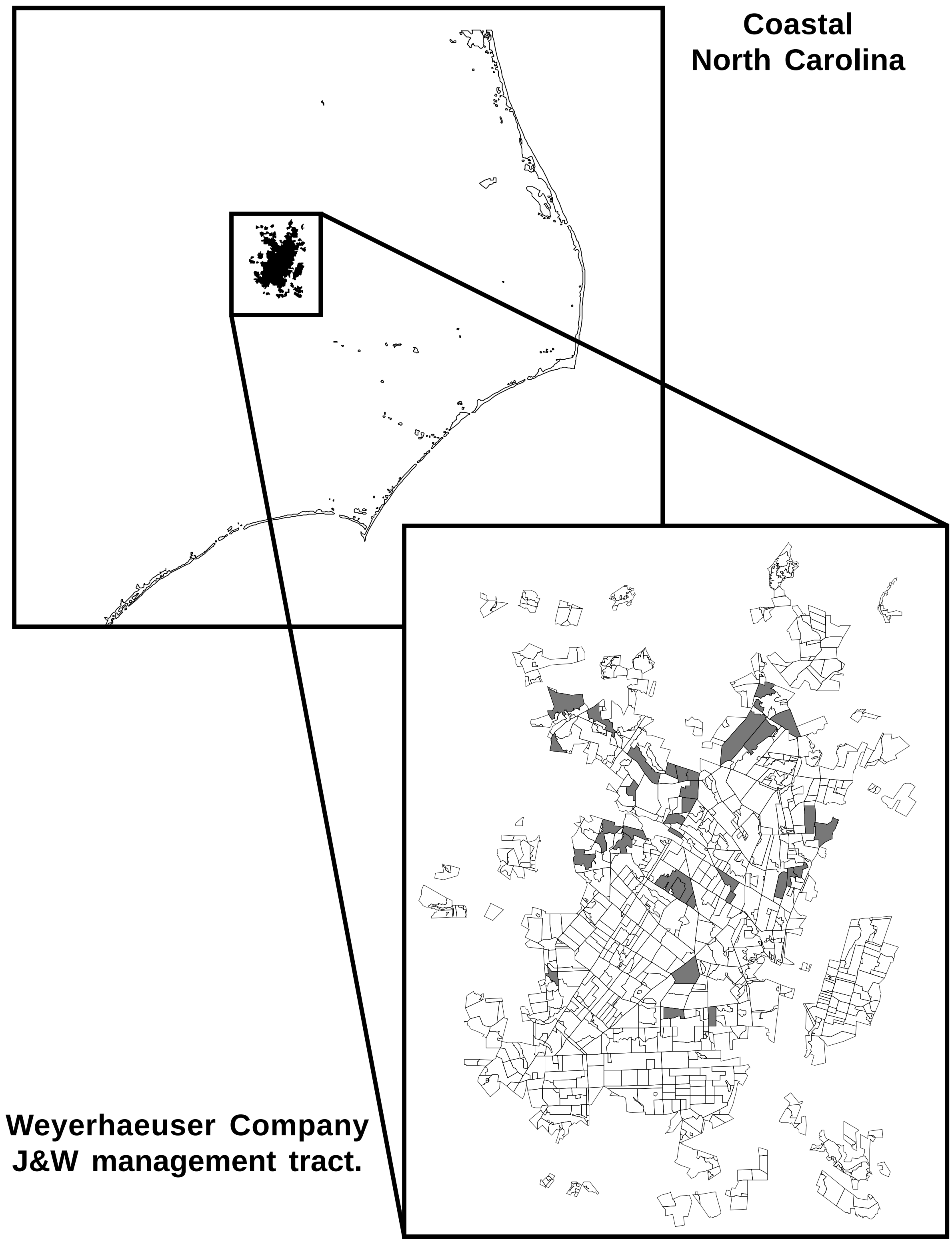

Figure 1. Map of study area within Weyerhaeuser Company J&W management tract. Management stands used are shaded gray.

Table 1. List of stands used with ages and age class codes.

Stand Number	Age	Age Class Code
42607	Pre-thin,chopped	1
45153	Pre-thin,chopped	1
42402	Pre-thin,chopped	1
42430	Pre-thin,chopped	1
42792	Pre-thin,chopped	1
45212	1-2 years after first commercial thin	2
45071	1-2 years after first commercial thin	2
44931	1-2 years after first commercial thin	2
42036	1-2 years after first commercial thin	2
44990	1-2 years after first commercial thin	2
42003	3-4 years after first commercial thin	3
44830	3-4 years after first commercial thin	3
44715	3-4 years after first commercial thin	3
44406	3-4 years after first commercial thin	3
42385	3-4 years after first commercial thin	3
44298	5-6 years after first commercial thin	4
44306	5-6 years after first commercial thin	4
42009	5-6 years after first commercial thin	4
44026	5-6 years after first commercial thin	4
44299	5-6 years after first commercial thin	4
42155	1-2 years after second commercial thin	5
44429	1-2 years after second commercial thin	5
42469	1-2 years after second commercial thin	5
42470	1-2 years after second commercial thin	5
42682	1-2 years after second commercial thin	5
42154	3-4 years after second commercial thin	6
42206	3-4 years after second commercial thin	6
42472	3-4 years after second commercial thin	6
42015	3-4 years after second commercial thin	6
42444	3-4 years after second commercial thin	6
42406	5-6 years after second commercial thin	7
42463	5-6 years after second commercial thin	7
44621	5-6 years after second commercial thin	7
42462	5-6 years after second commercial thin	7
42739	5-6 years after second commercial thin	7

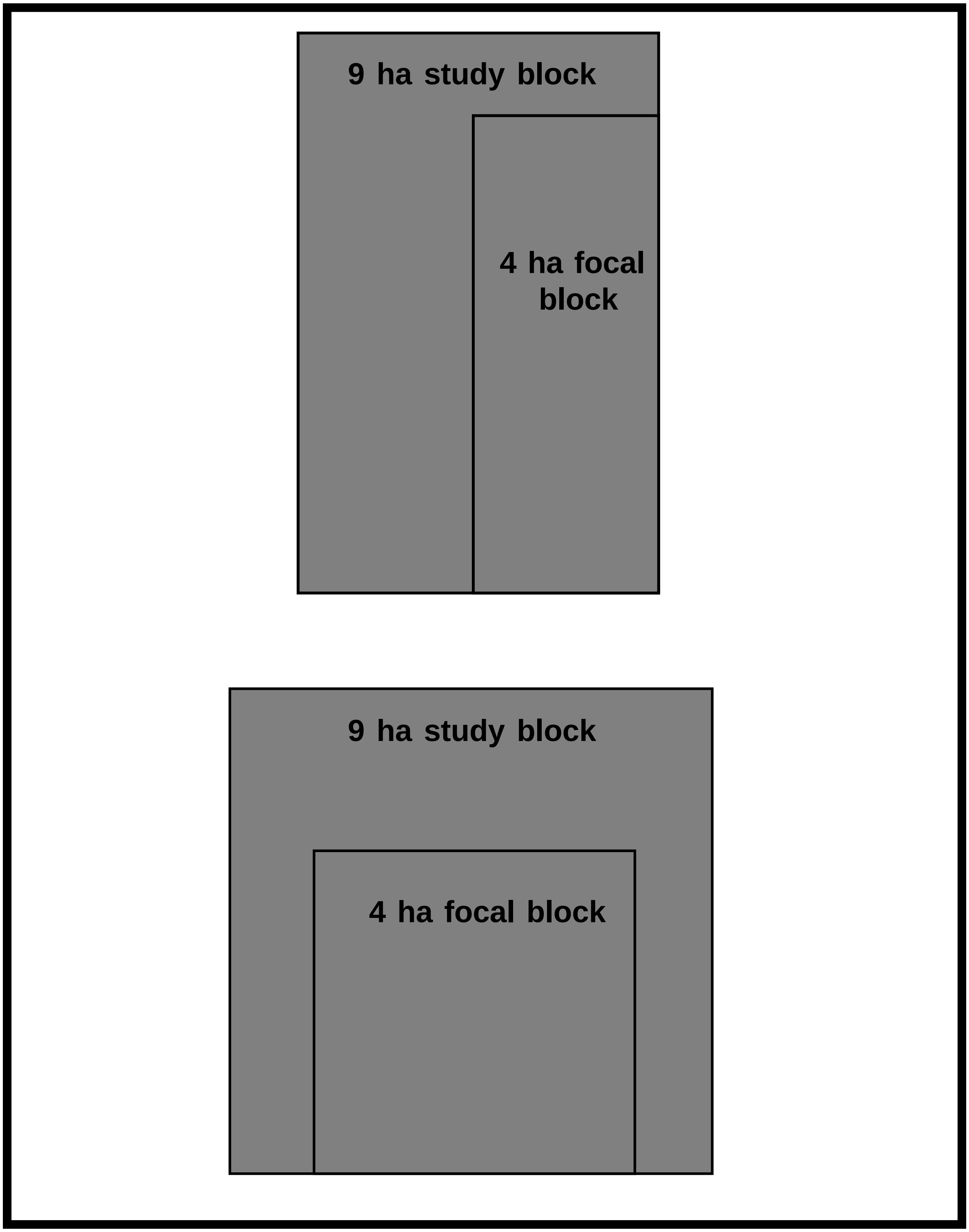

Figure 2. Two examples of study plot arrangement. Each study block consisted of a 4-ha focal block within a larger 9-ha study block.

stem, number of limbs $\geq$1 m projecting from the main stem, height to first limb, visual estimate of bark remaining on main stem, presence or absence of needles, number of cavities, cavity heights, cavity orientations, cavity hole diameter, cavity structure, and cavity use. The height of the snag, first limb, and cavity was measured in meters using a 15-m measuring pole or clinometer depending on individual heights. DBH was measured to the nearest 0.1 cm using a diameter tape. Cavity-hole diameter was measured to the nearest cm with the aid of the height pole or visually estimated. Cavity structures recorded included; main stem, limb scar, lateral limb and natural cavity. Cavities were considered in use if birds were observed entering and/or exiting cavities, or if birds were flushed or chicks vocalized after observers tapped the main stem with a 0.5-m long 2.5-cm diameter PVC pipe. All snags within the 4-ha focal block were surveyed between 5 May 2002 and 17 May 2002, while all snags in the remaining portion of the 9-ha block were surveyed from 5 May 2002 to 15 July 2002. Snags within the 4-ha focal block were resurveyed in July 2002 to identify any obvious changes in structure.

Field technicians Danni Larson and Sandra Smith measuring the height of a snag with a height pole. photo by Bart Paxton

Field technicians Danni Larson and Sandra Smith measuring the DBH of a snag with a diameter tape. photo by Bart Paxton

Data were collected on the vegetation surrounding all snags within the 4-ha focal block and all cavity bearing snags within the remaining portion of the 9-ha block. Vegetation was surveyed within a 3-m radius circle, the center of which was the snag base. Each circle was divided 3 concentric circles 1 m apart. Circles were divided into quadrants based on the cardinal compass points, resulting in 12 survey segments (Figure 3). The total number of stems $\geq$ 0.1 meter and the height of the tallest stem were recorded for each segment.

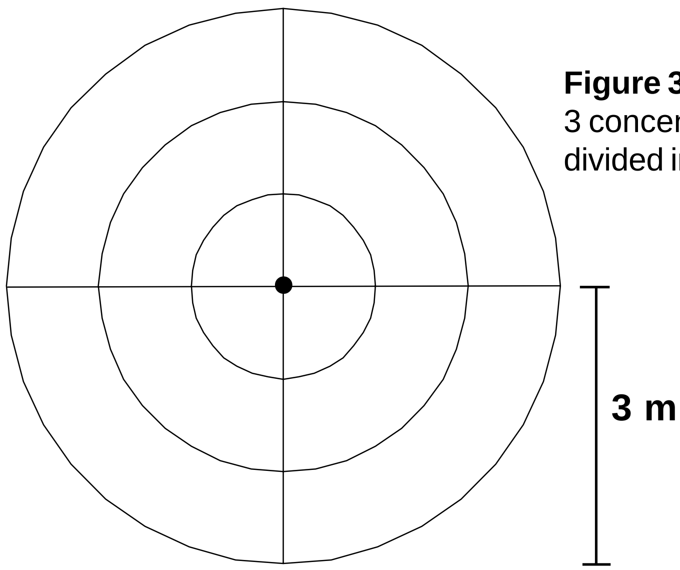

Figure 3. Vegetation survey plot consisting of 3 concentric circles spaced 1 m apart and divided into quadrants.

Cavity Monitoring

All cavity-bearing snags identified, marked, mapped, and characterized during the initial snag survey were revisited once every 18-day period to check for nesting activity. Snags were approached while watching for birds entering and/or exiting cavities. If no birds were observed the trunk was tapped with a 0.5-m long 2.5-cm diameter PVC pipe to elicit vocalizations from any chicks present or to flush out adults. Selected cavities were also inspected with a Treetop II video camera system to confirm absence of nesting activities.

Bird Surveys

Birds were surveyed along a single 300-m transect within the 9-ha study block of each of the 35 study stands. Birds were surveyed form 3 June 2002 to 19 July 2002, and between sunrise and 4 hours after sunrise. Surveys were conducted using a standard variable width transect technique (Emlen, 1971). The observer would walk slowly and steadily along the transect line, looking and listening for birds within 100 m (perpendicular distance) of the transect line. All birds encountered were identified to species and recorded on field data sheets. Also recorded were the initial method of detection (visual, aural, or flush), estimated detection distance and estimated perpendicular distance off of the transect line.

Data Analysis

Snags were grouped into arbitrary DBH and bark classes. The 5 DBH classes included 1) 8-11.9, 2) 12-15.9, 3)16-19.9, 4) 20-24.9, and 5) $\geq$ 25 cm. Bark classes used included 1) 90-100, 2) 75-89, 3) 50-74, 4) 25-49 and 5) 0-24 % bark remaining on main stem. All snags were also classified into on of five decay classes based on the presence or absence of needles, percentage of bark remaining on the main stem, presence or absence of lateral limbs (Table 2).

Snag and habitat data were summarized to make comparisons between stand age classes, and snag condition. To make comparisons between snags with and without cavities and used and unused cavities data was summarized using all stand age classes and only the stand age classes containing the greatest proportion of cavity bearing snags. Non-parametric, univariate tests were used to compare snag and habitat data among all age classes and for snag and habitat data measured on ordinal scales. Kruskal-Wallis and Mann-Whitney U tests were used for multi-level and pairwise level comparisons respectively. For comparisons of snag characteristic and vegetation measurements between snags with and without cavities and used and unused cavities in the older stand age classes ANOVA and t-tests were used.

Bird survey data were summarized to produce species richness and overall bird abundance values for each stand age. Species richness was calculated for individual stands by taking the cumulative number of species detected on both transect counts. Insufficient bird numbers prevented accurate estimations of densities, so overall bird abundance was calculated by dividing the total number of birds detected on both transect counts to produce a value of the number of birds/100 m of transect. Numbers of primary and secondary cavity users detected within the different stand age classes were compared.

Table 2. Criteria used to place snags into decay classes.

Decay Class	Needles Present	Bark Remaining	Limbs Present
1	Yes	> 90%	Yes
2	Yes	</= 90%	Yes
3	No	>75%	Yes/No
4	No	51-75%	No
5	No	</=50%	No

Results

A total of 1,186 snags were identified and characterized within the 35 study blocks. Snags were not evenly distributed throughout stand age classed (Figure 4). Total snag numbers peaked 1-2 years after the first commercial thin and overall snag numbers declined as the plantation stands matured. The mean number of snags ranged from 6.13 snags/ha (± 5.75 SD) in stands 1-2 years after fist thin to 1.98 snags/ha (± 1.06 SD) in stands 3-4 years after second thin (Figure 5) (see Figures 6 and 7 for graphic examples of stands with high and low densities of snags). Stand age class also had significant effects on all snag and vegetation variables measured (Table 3 and Figures 8 through 14). Percentage of bark remaining on the main stem and DBH were two variables effected most by stand age class. As stands mature the proportion of snags within the higher bark classes increase (Figure 15). The proportion of snags within each DBH class was skewed toward the lower DBH classes in the younger stands and shifted towards the higher DBH classes as the stands matured (Figure 16). Also observed was a precipitous drop in the number of smaller snags immediately following the second commercial thin.

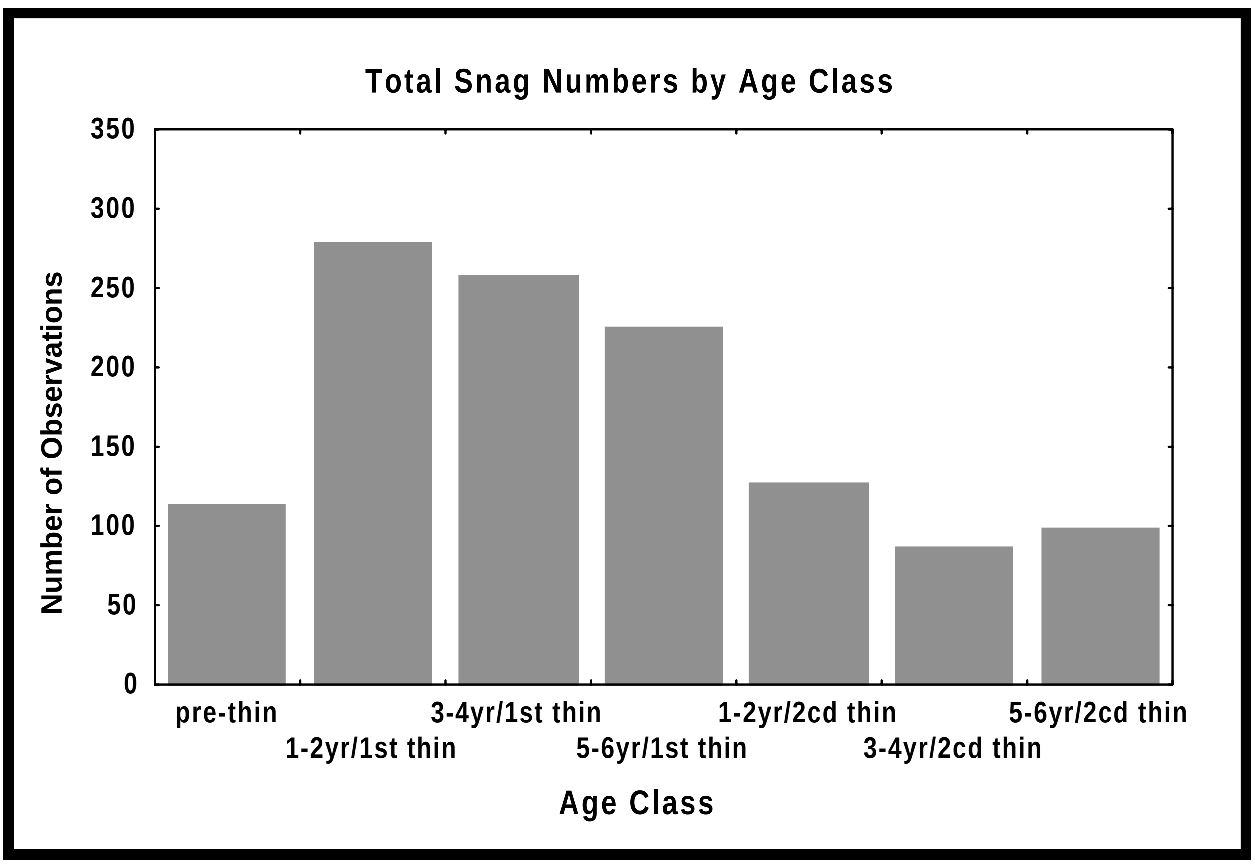

Figure 4. Total number of snags identified within each age class.

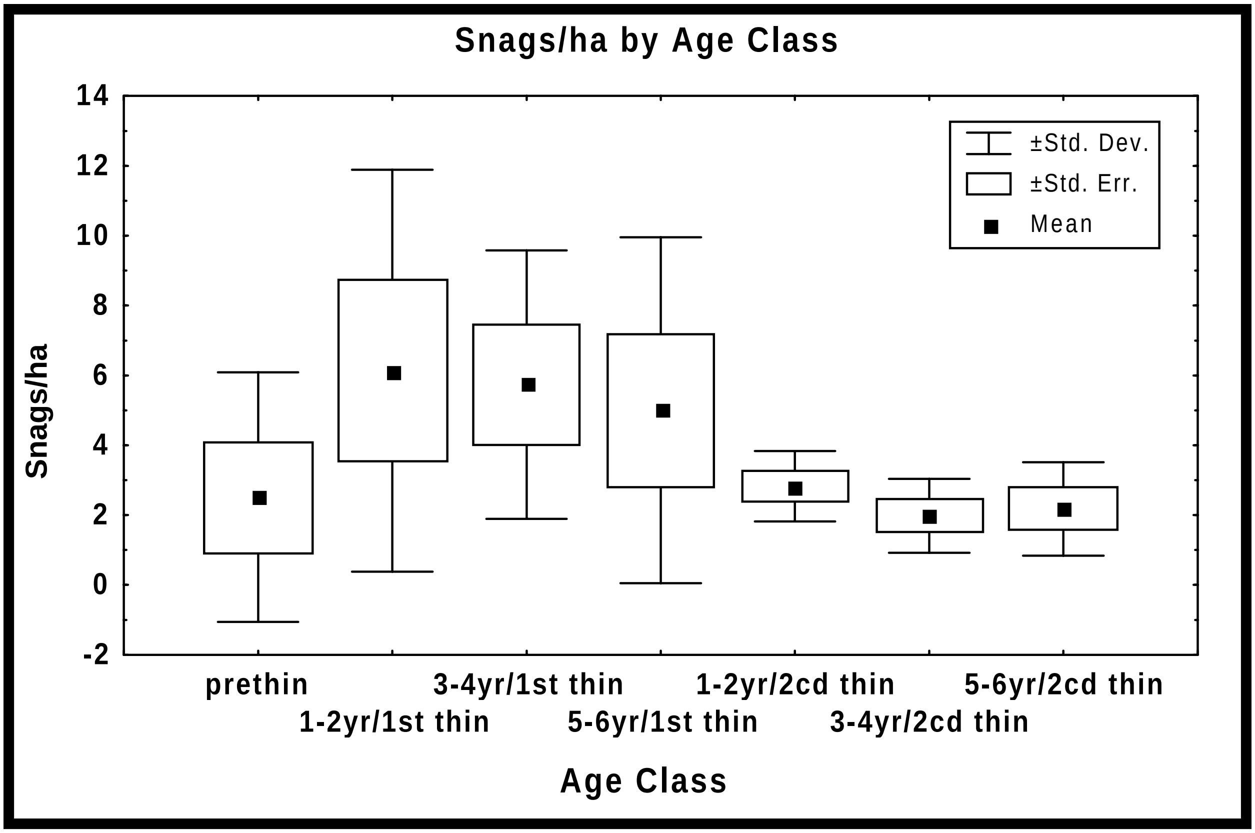

Figure 5. Mean number of snags/ha by age class.

Table 3. Kruskal-Wallace and Spearman rank correlation results for the effect of stand age on snag and vegetation variables.

Variable	H-statistic	p value	Spearman r	p value
Height	175.71	< 0.0001	0.33	< 0.0001
DBH	317.97	< 0.0001	0.49	< 0.0001
DBH Class	308.59	< 0.0001	0.48	< 0.0001
Total Limbs	256.79	< 0.0001	-0.04	> 0.05
Height to 1st Limb	114.33	< 0.0001	0.14	< 0.0001
Decay Class	354.71	< 0.0001	0.37	< 0.0001
Bark Class	324.67	< 0.0001	0.39	< 0.0001
% bark remaining	308.52	< 0.0001	-0.40	< 0.0001
Stem/m^2	130.4	< 0.0001	-0.14	<0.01
Mean vegetation height	31.93	< 0.0001	0.11	<0.05

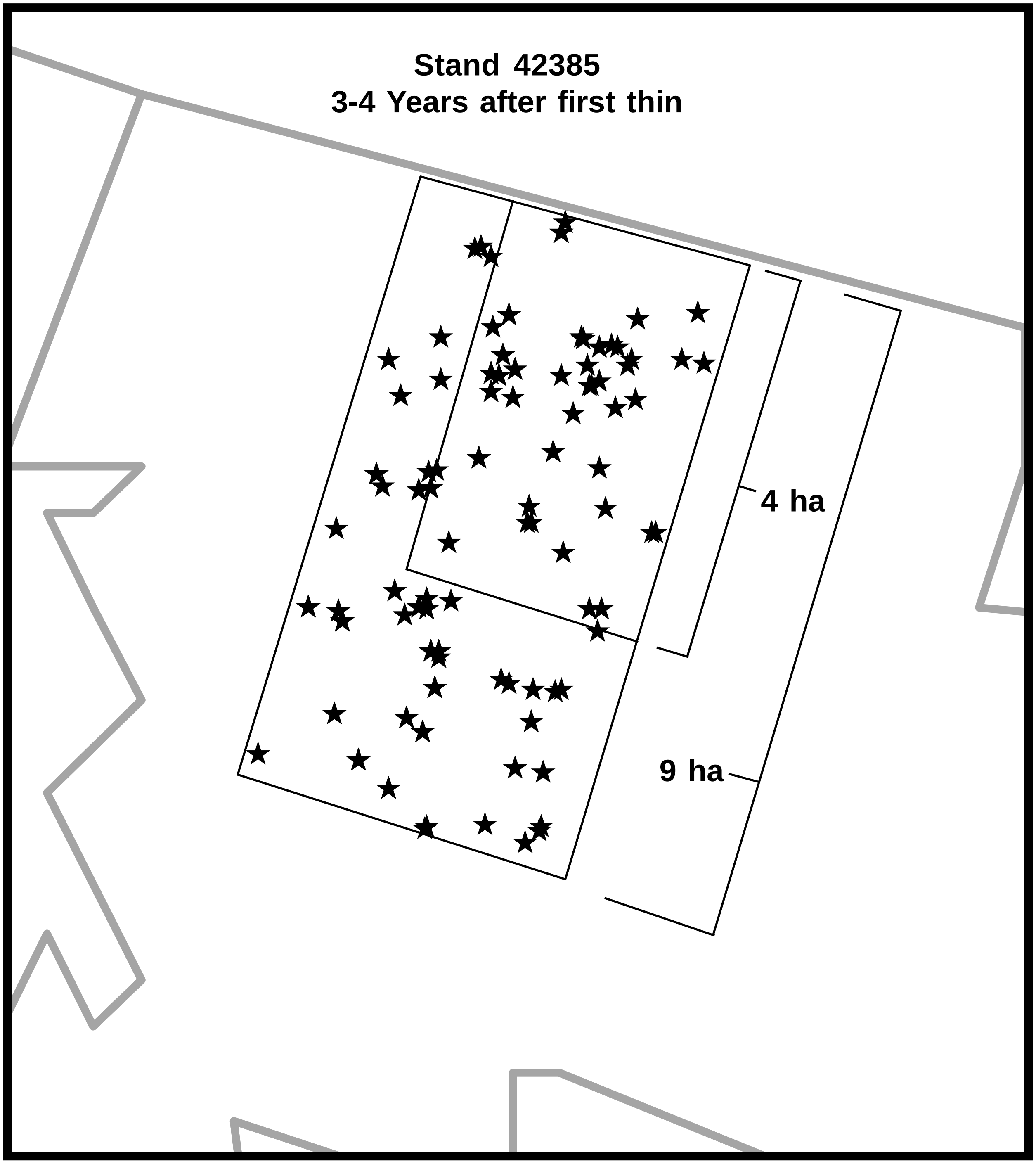

Figure 6. Example of stand with high density of snags (snags indicated by stars).

Figure 7. Example of stand with low density of snags (snags indicated by stars).

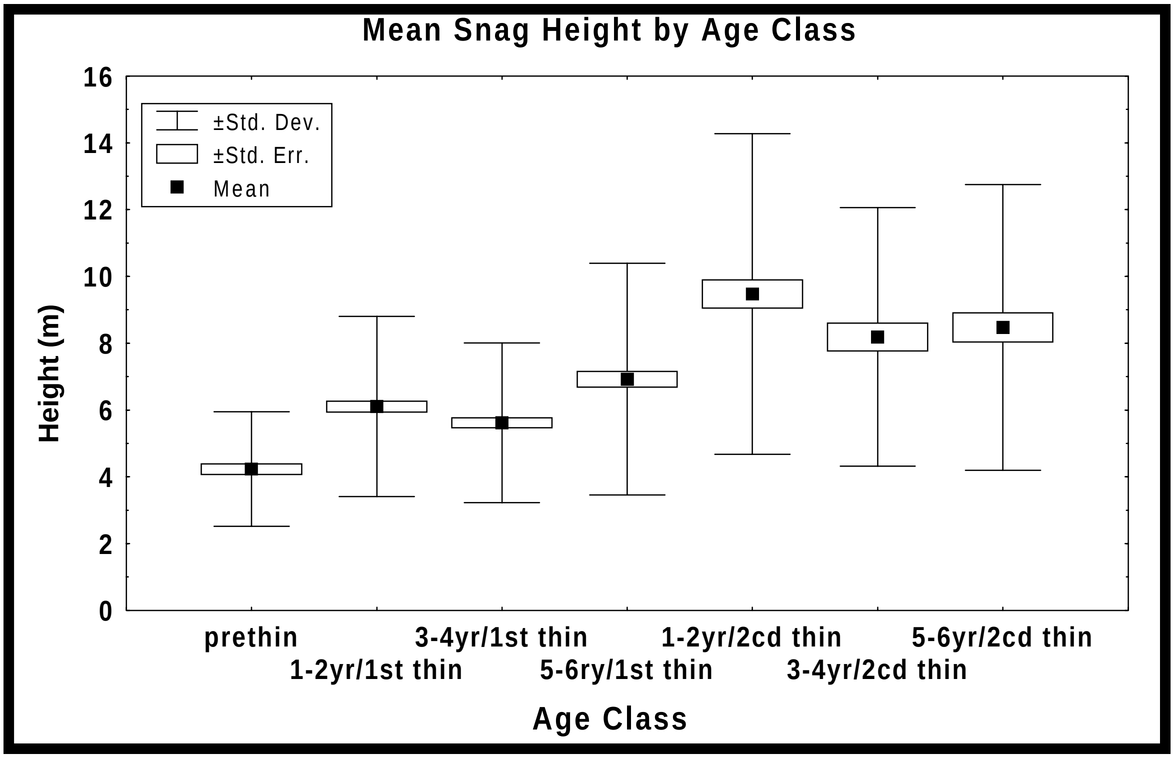

Figure 8. Mean snag height for all snags identified within each age class.

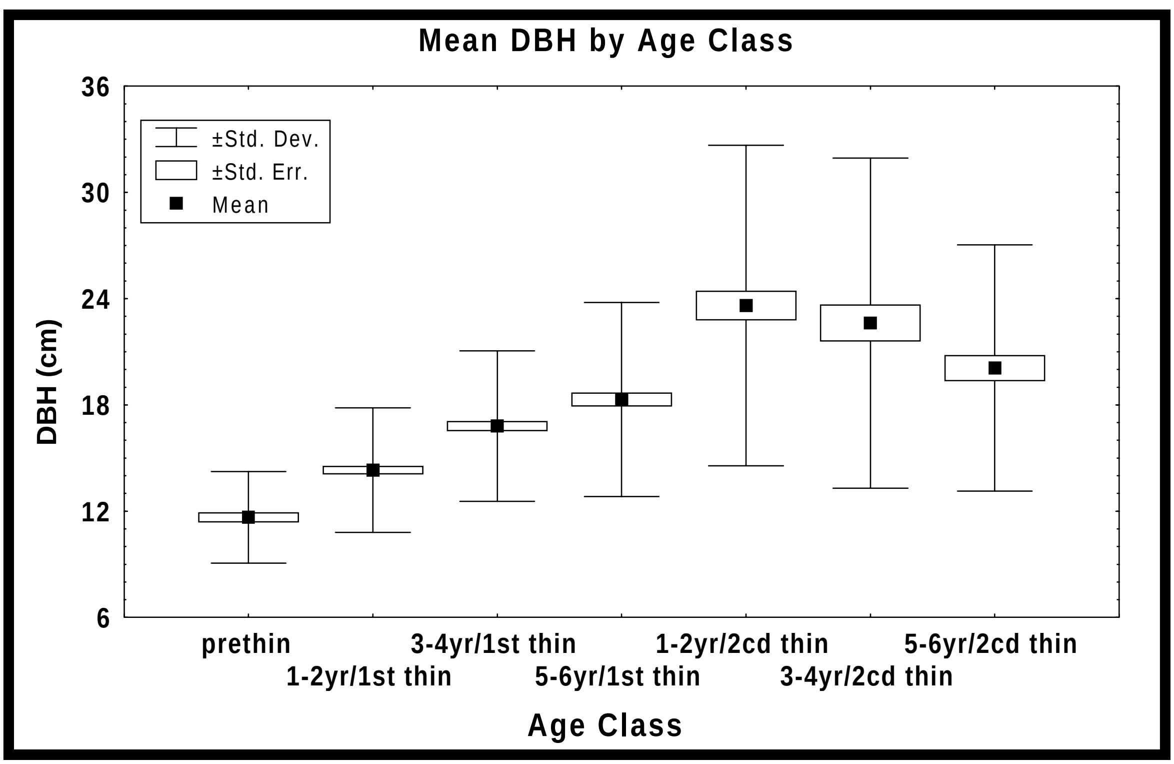

Figure 9. Mean snag DBH for all snags identified within each age class.

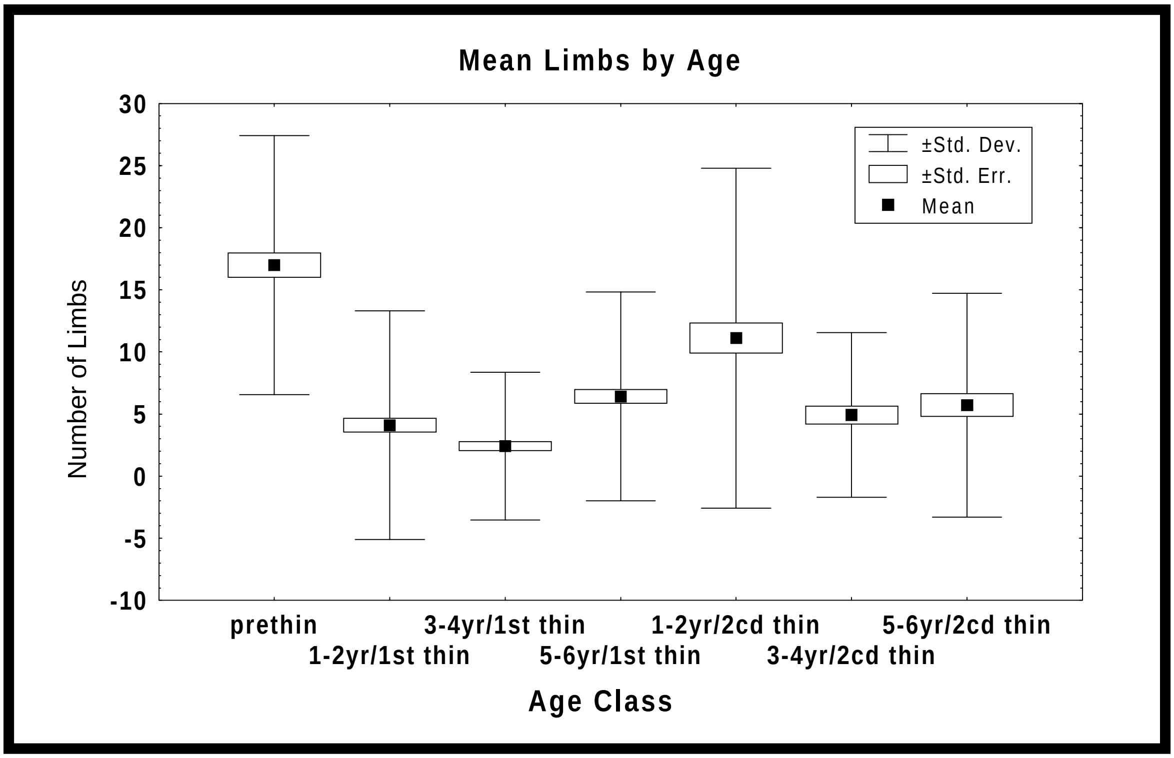

Figure 10. Mean number of limbs remaining for all snags identified within each age class.

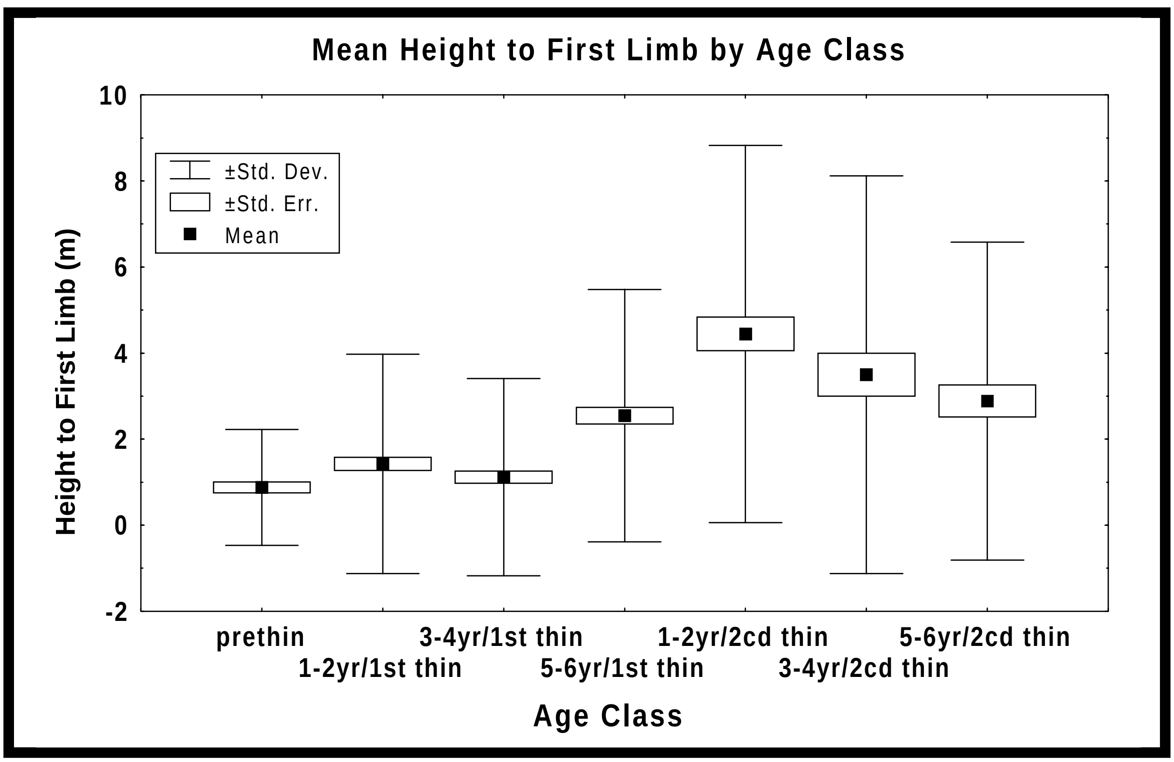

Figure 11. Mean height to first limb for all snags identified within each age class.

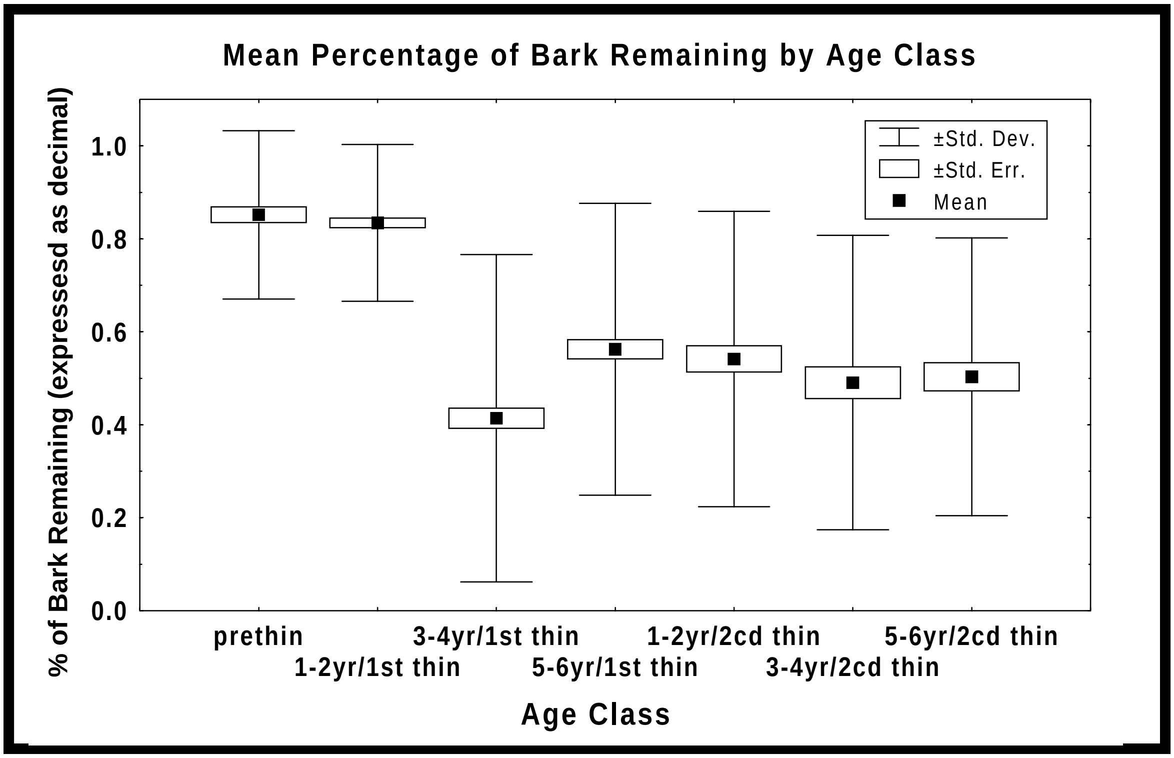

Figure 12. Mean pecentage of bark remaining on main stem for all snags identified within each age class.

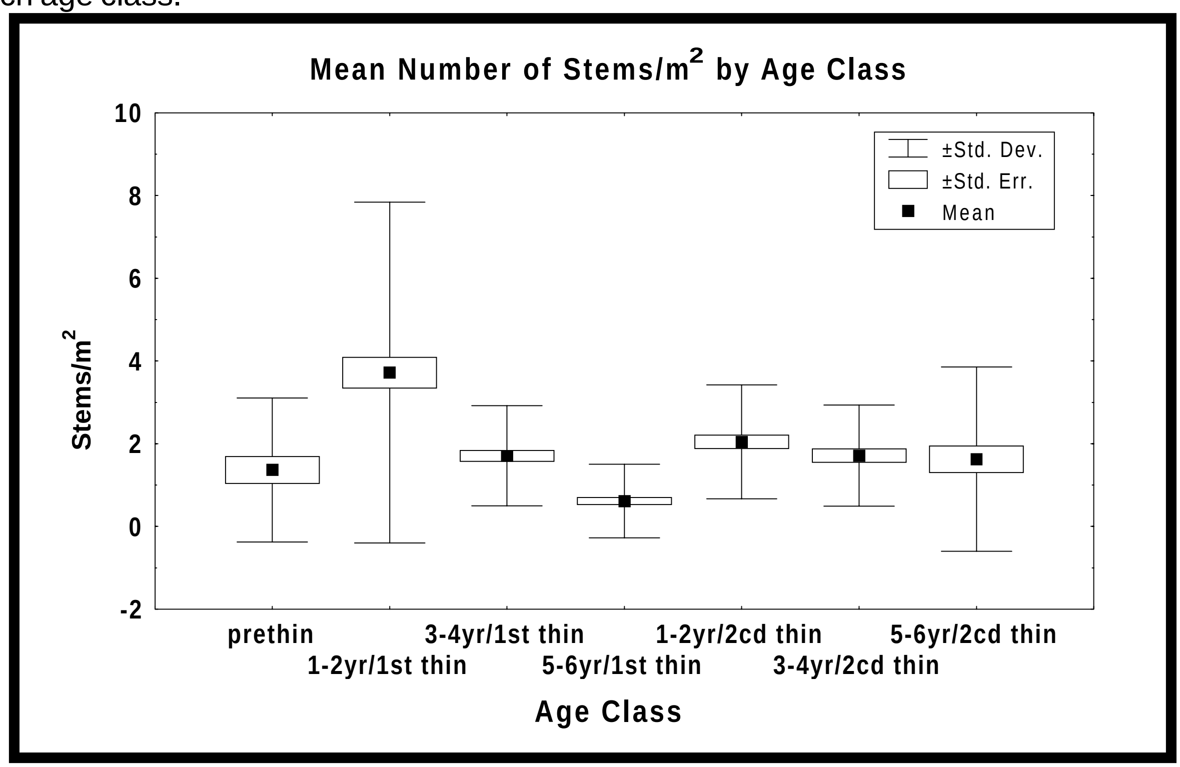

Figure 13. Mean number of stems/m^2 for all snags identified within each age class.

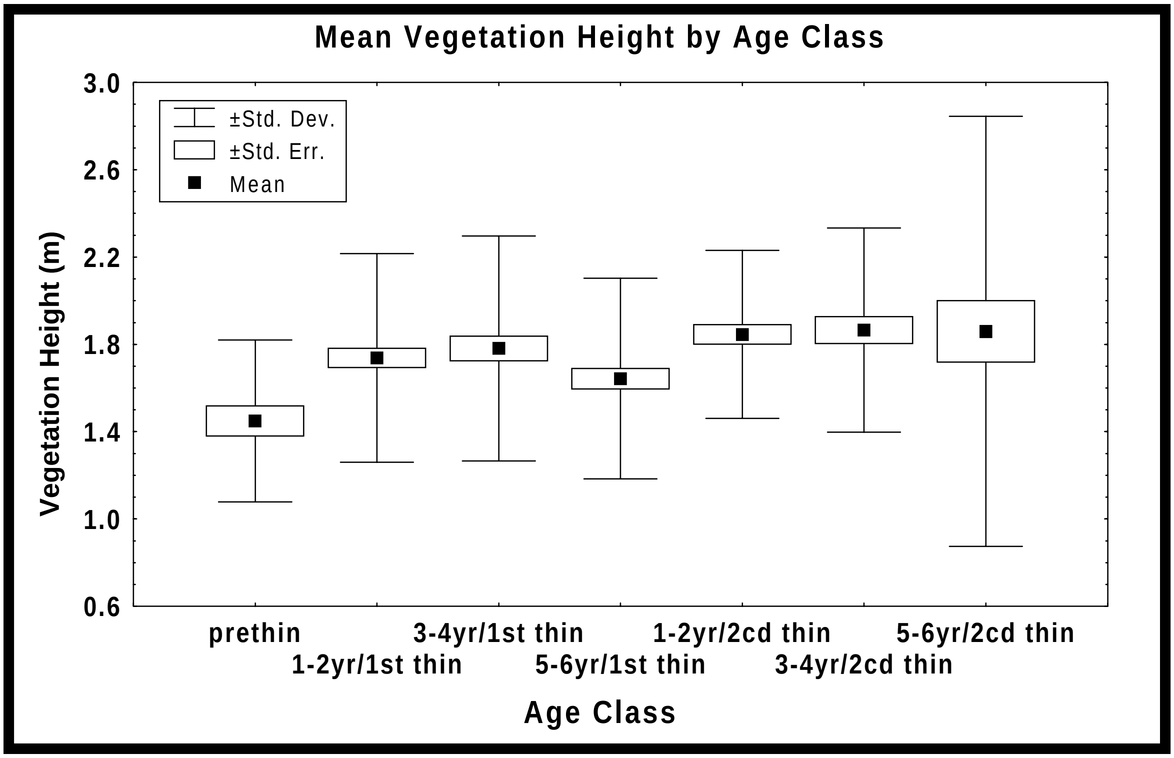

Figure 14. Mean vegetation height for all snags identified within each age class.

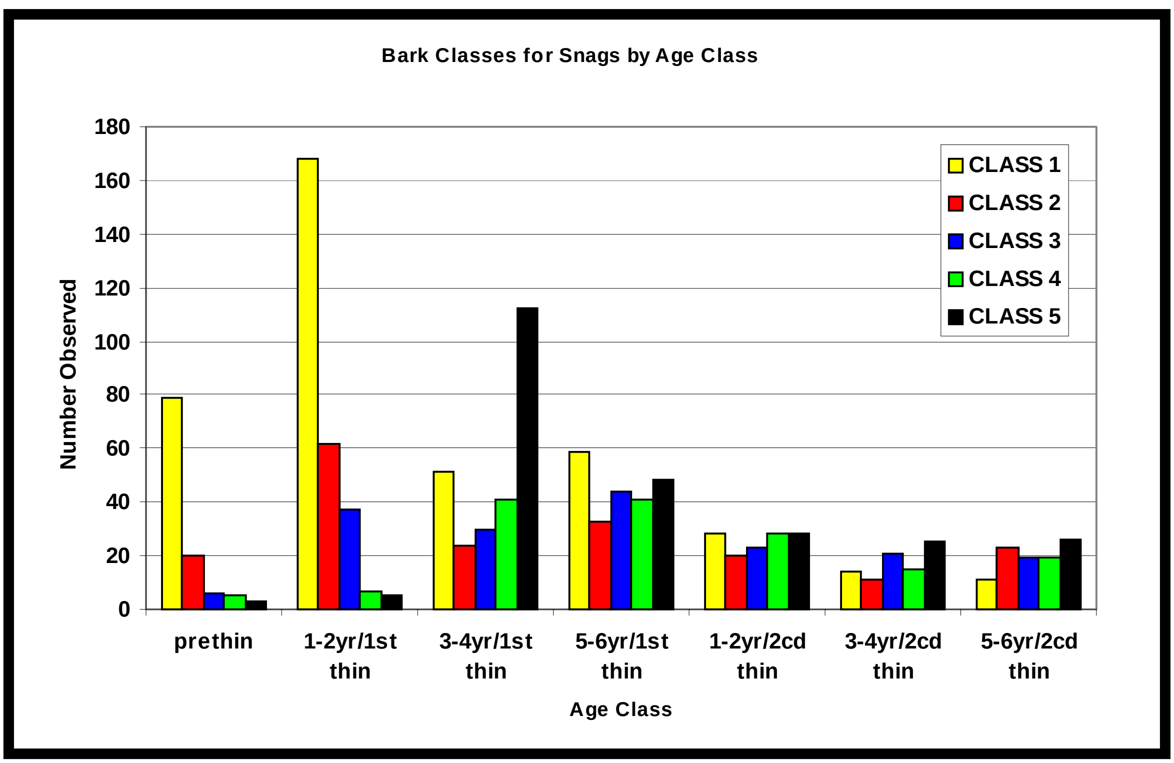

Figure 15. Number of snags observed exhibiting each bark class for all snags identified within each age class.

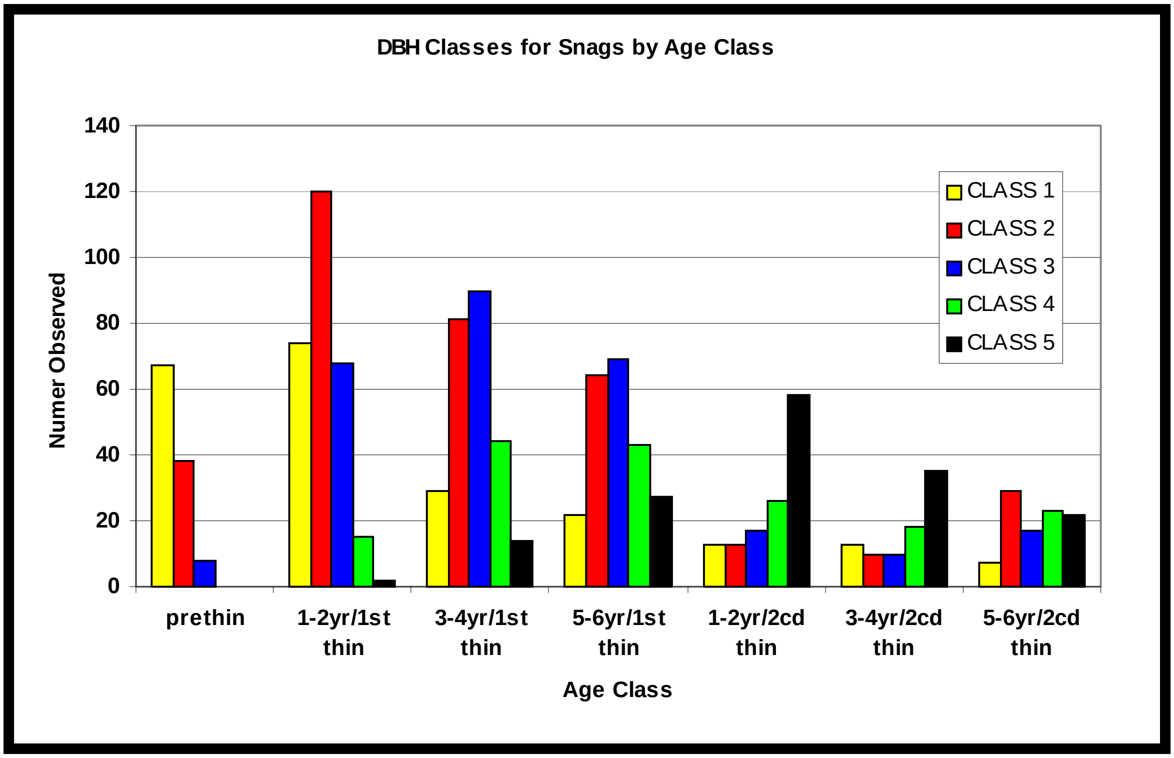

Figure 16. Number of snags observed within each DBH class for all snags identified within each age class.

Of the 1,186 snag identified, 116 or 9.78% had one or more cavities. Cavity-bearing snags were not evenly distributed among age (x^2=83.95, p<.0001), DBH (x^2=59.94, p<.0001), decay (x^2=67.94, p<.0001), and bark classes (x^2=70.45, p<.0001). Among age classes, cavity-bearing snags occurred at higher than expected frequencies in age classes 5-6 years after first thin and older (Figure 17). Within DBH classes, snags with cavities occurred at higher than expected frequencies in the 3 classes with the greatest DBHs (Figure 18). Among decay and bark classes, cavity-bearing snags occurred at higher than expected frequencies in the 2 classes that represent the greatest amount of decay and the 3 classes with the least amount of bark remaining on the main stem respectively (Figures 19 and 20).

Individual snag characteristics were compared between all snags with and without cavities. Significant differences were found in the variables height, DBH, DBH class, height to first limb, decay class, bark class, % remaining bark, and mean vegetation height (Table 4). Individual characteristics were also compared between the 65 snags with cavities and the 156 snags without cavities that were present in the combined class groups with higher than expected frequencies of cavity-bearing trees (age class 4-7, DBH class 3-5, decay class 4-5, and bark class 3-5) (Table 5). Snags with cavities were generally taller, had greater DBHs and distances to first limbs, and had fewer total limbs and less remaining bark than snags without cavities. However, only the amount of bark remaining was

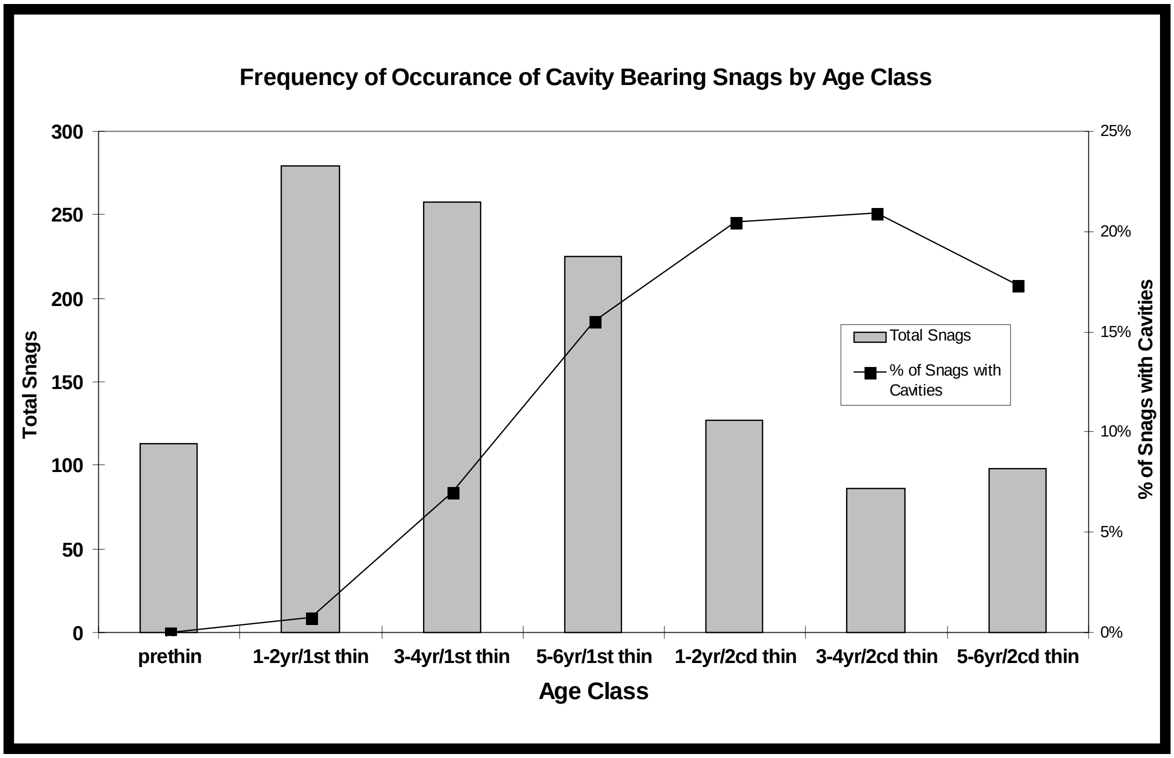

Figure 17. Freqency of occurance of cavity-bearing snags compared to all snags identified within each age class.

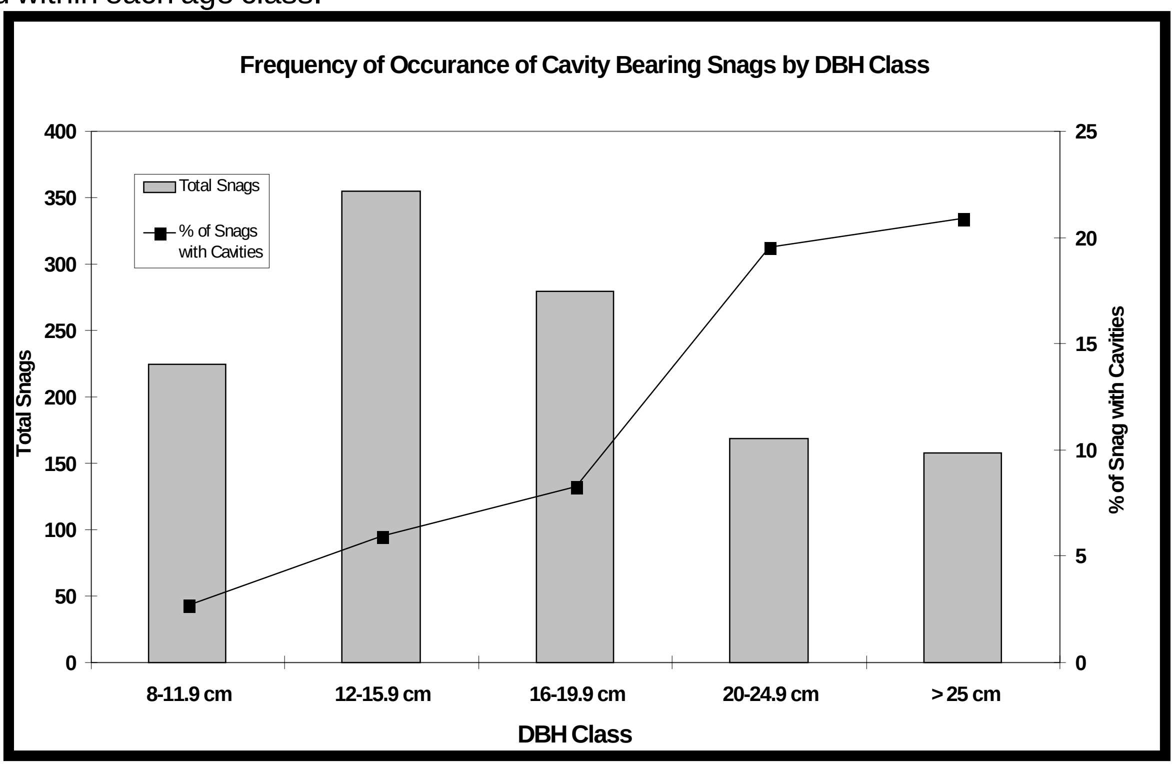

Figure 18. Freqency of occurance of cavity-bearing snags compared to all snags identified within each DBH class.

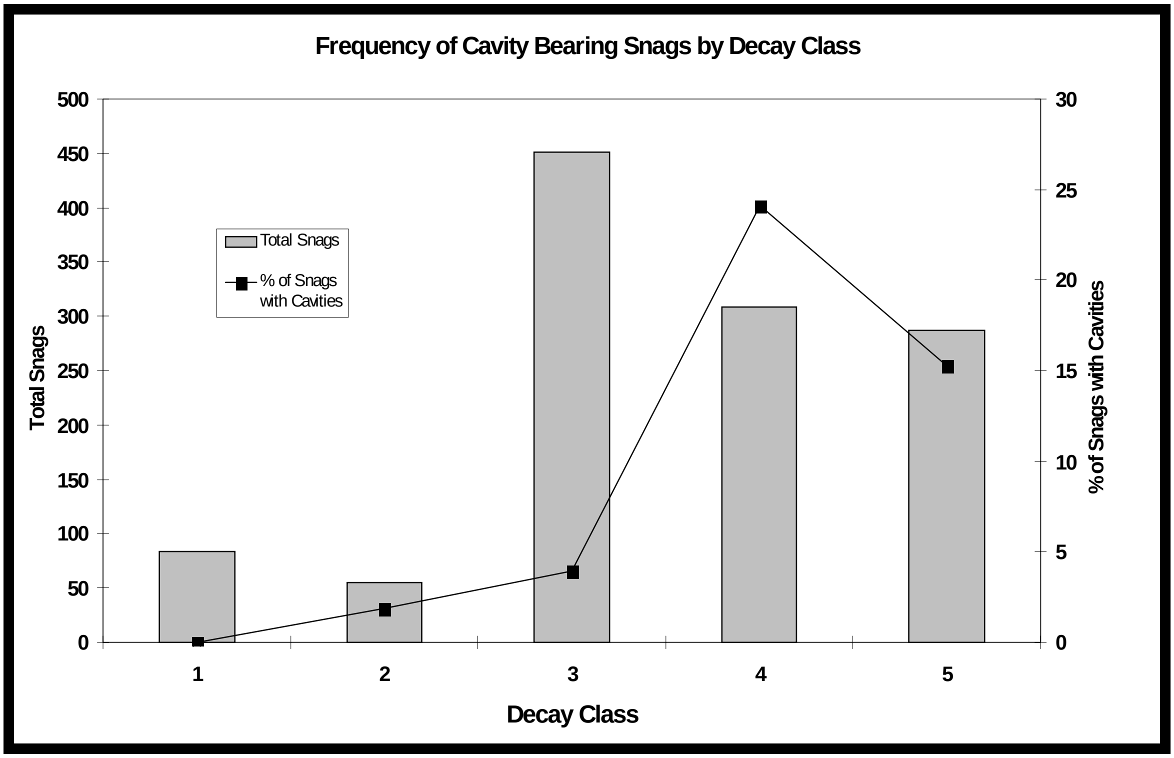

Figure 19. Freqency of occurance of cavity-bearing snags compared to all snags identified within each decay class.

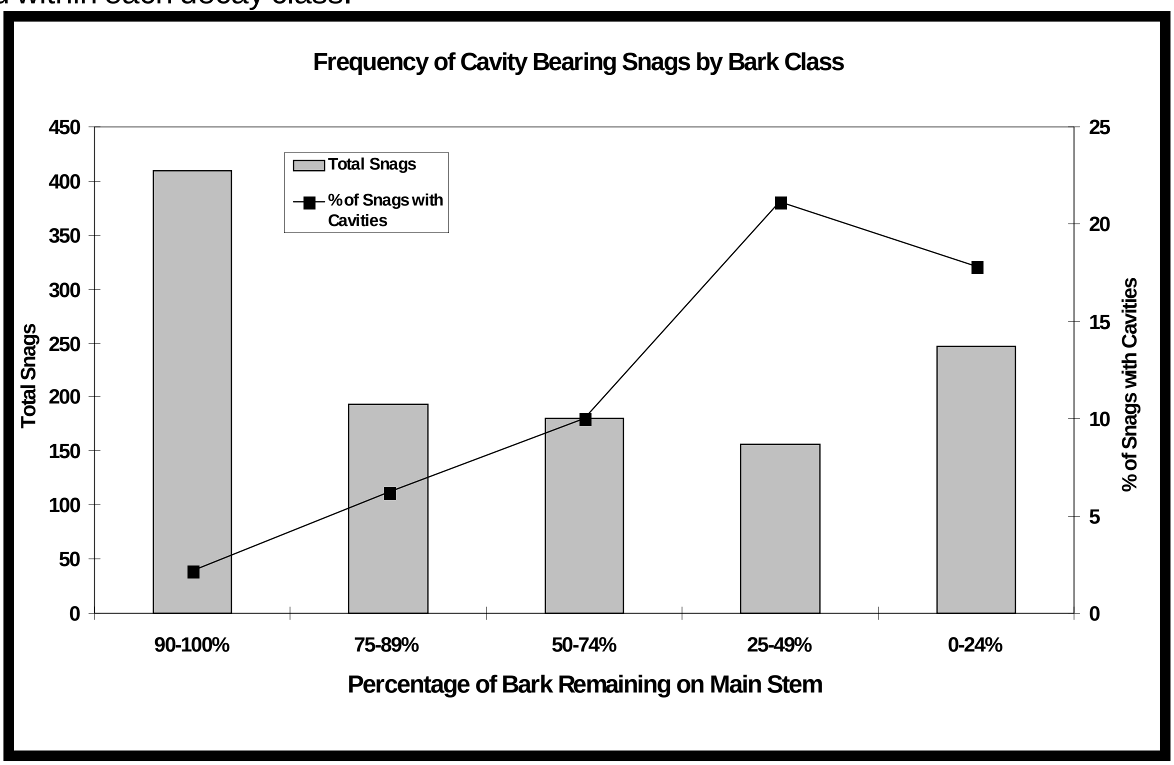

Figure 20. Freqency of occurance of cavity-bearing snags compared to all snags identified within each bark class.

Table 4. Results of Mann-Whitney U tests for comparison of snag and vegetation variables between all cavity-bearing snags and non-cavity-bearing snags.

Variable	Mann-Whitney U	p value	N (with cavities, without cavities)
Height	50414	<0.001	116, 1070
DBH	36427	<0.0001	116, 1070
DBH Class	37505.5	>.05	116, 1070
Total Limbs	59397.5	<0.001	116, 1070
Height to 1st limb	50000.5	<0.0001	116, 1070
Decay Class	40255	<0.0001	116, 1070
% bark remaining (dec.)	35288	<0.0001	116, 1070
Bark Class	34710.5	<0.0001	116, 1070
Stems/m^2	19167	>0.05	95, 416
Mean Vegetation Height	15307.5	<0.001	95, 416

Table 5. Student t-test results for comparison of snag and vegetation variables between snags with and without cavities from the combined age, DBH, decay and bark classes with higher than expected frequencies of cavity-bearing snags.

Variable	Mean value for snags with cavities ± SD	Mean value for snags without cavities ± SD	t value	p value	N (with cavities, without cavities)
Height	8.54 ± 4.02	8.37 ± 4.39	0.26	>0.05	65, 156
DBH	24.46 ± 6.48	23.68 ± 5.70	0.89	>0.05	65, 156
Total Limbs	5.54 ± 7.38	6.36 ± 9.78	-0.61	>0.05	65, 156
Height to 1st limb	4.18 ± 4.47	3.15 ± 4.17	1.65	>0.05	65, 156
% bark remaining (dec.)	.29 ± .20	.36 ± .22	-2.21	<0.05	65, 156
Stems/m^2	1.55 ± 1.53	1.51 ± 1.66	0.10	>0.05	51, 69
Mean Vegetation Height	1.94 ± 6.1	1.77 ± .65	0.17	>0.05	51, 69

found to be significant (Figure 21). The number of cavities per snag ranged from 1 to 12 and showed a positive correlation to stand age (Figure 22), DBH (Figure 23), and bark class (Figure 24).

Of the 116 cavity-bearing snags identified, 12 or 10.34% were confirmed as being used for nesting. Examination of selected cavities with the video camera system did not reveal any previously unidentified nests. Nesting activity was observed for 5 species in 10 stands spanning 5 age classes (Table 6). Nesting was observed in all age classes except pre-thin and 1-2 years after first thin. No significant differences were found in frequency of cavity use when compared to bark, decay, DBH, and age classes. Comparison of individual characteristics from used and unused cavity bearing snags also resulted in no significant differences being found (Table 7).

Along transects within all of the study plots, 908 detections were made of 37 species (Appendix I). Common yellowthroats, eastern towhees, white-eyed vireos, and gray catbirds were the most commonly detected species, accounting for nearly 64% of all observations (Appendix II). Average species richness varied significantly among stand ages classes (Kruskal-Wallace H=12.88, p<.05), ranging from 7.2 to 11.8 (Table 8) and was found to be significantly and positively correlated with stand age (Pearson r=.37, p<.05) (Figure 25). No difference was found in overall bird numbers when compared with stand age classes. Cavity users, both primary and secondary, were not observed in appreciable numbers until after the first commercial thin. Similar numbers of cavity users were detected within the different stand age classes after the first commercial thin (Figure 26).

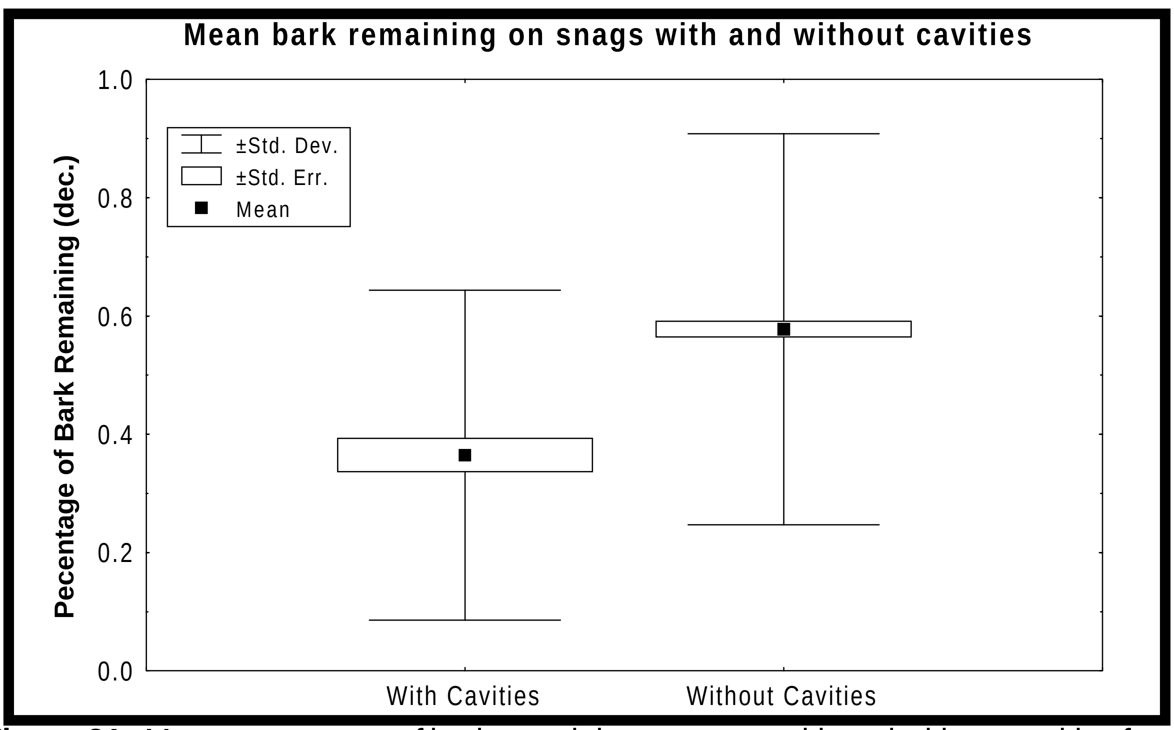

Figure 21. Mean percentage of bark remaining on snags with and without cavities from the combined age, DBH, decay and bark classes with higher than expected frequencies of cavity-bearing snags.

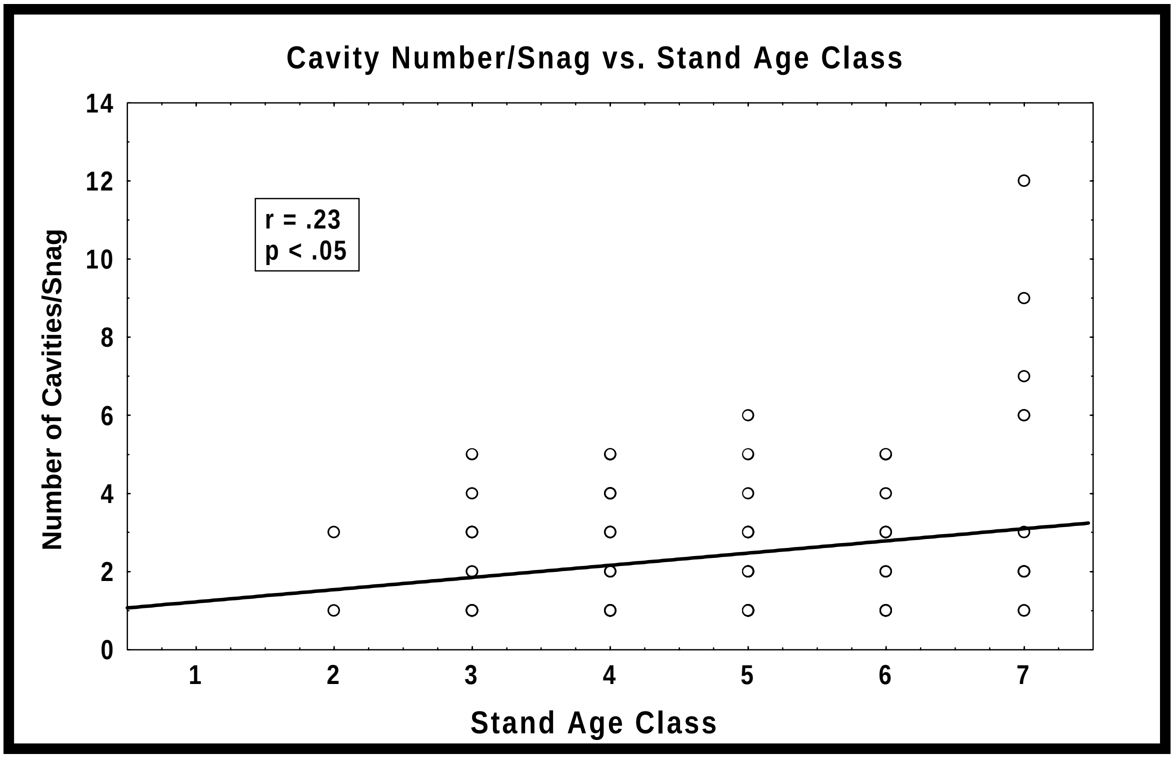

Figure 22. Scatter plot of number of cavities/snag vs. stand age class for all cavity-bearing snags.

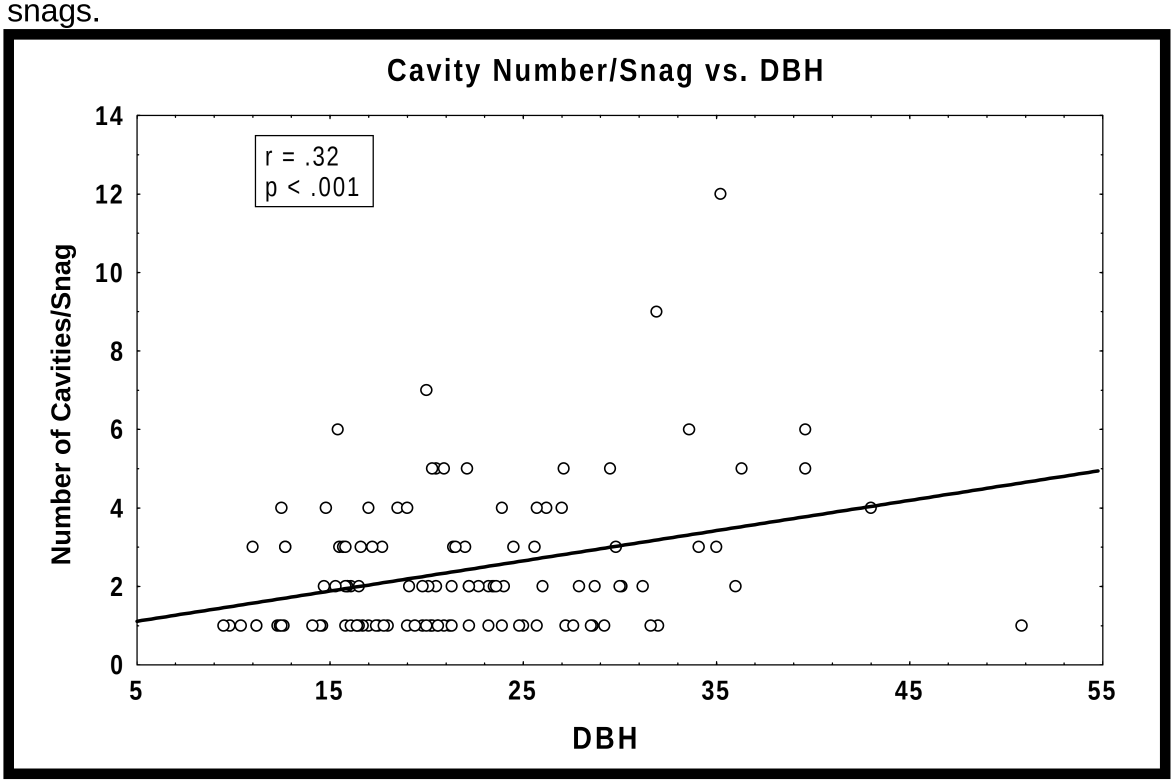

Figure 23. Scatter plot of number of cavities/snag vs. DBH class for all cavity-bearing snags.

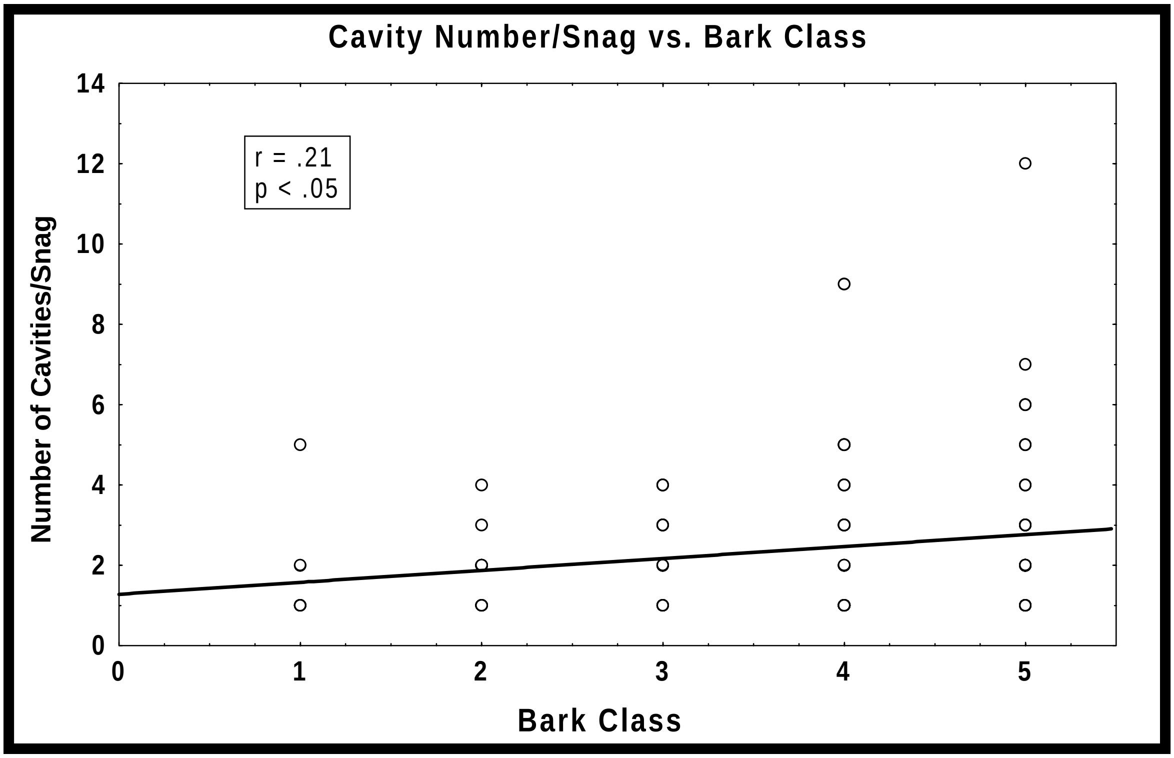

Figure 24. Scatter plot of number of cavities/snag vs. bark class class for all cavity-bearing snags.

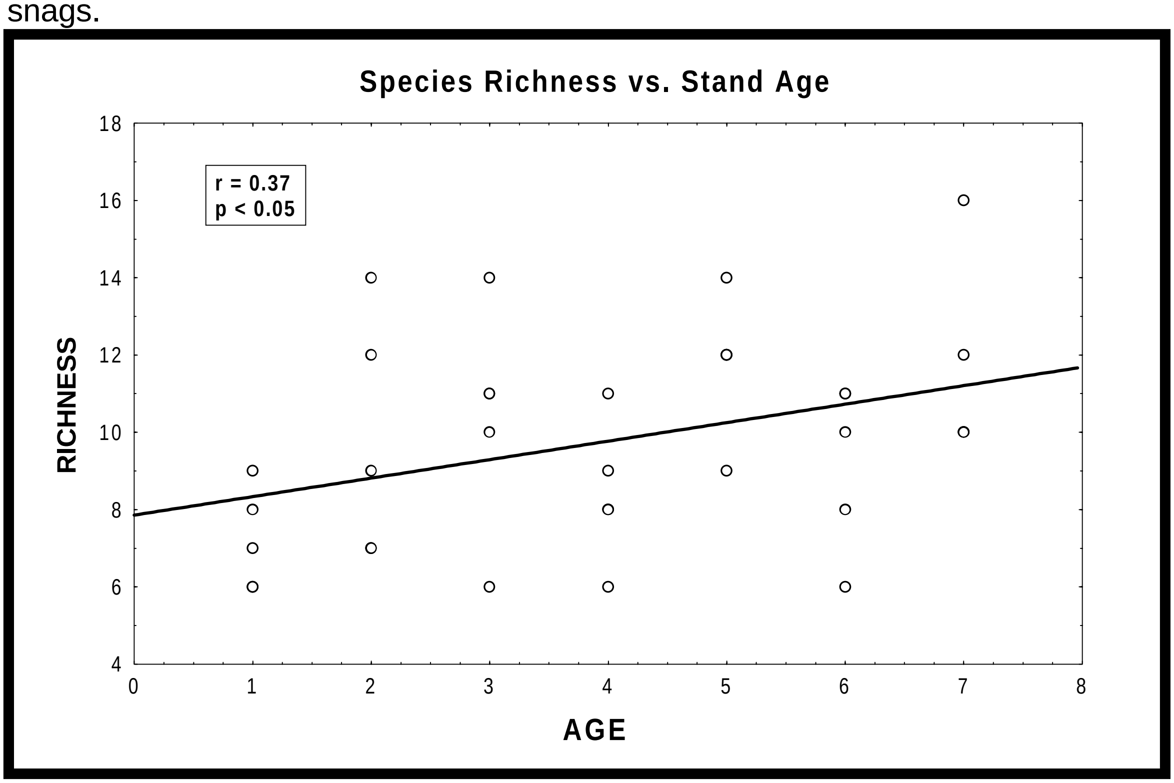

Figure 25. Scatter plot of number of cavities/snag vs. DBH class for all cavity-bearing snags.

Table 6. List of active nests detected in cavities, with species, stand number stand age, and selected snag characteristics.

Common Name	Scientific Name	Stand #	Stand Age	Snag Height	Snag DBH	% of Bark Remaining	Cavity Height
Carolina Chickadee	*Parus carolinensis*	42385	3-4 years after first thin	2.41m	14.1cm	95%	2.25m
Tufted Titmouse	*Parus bicolor*	44406	3-4 years after first thin	3.31m	21.3cm	20%	3.24m
Great-crested Flycatcher	*Myiarchus crinitus*	42003	3-4 years after first thin	3.85m	19.4cm	45%	3.75m
Great-crested Flycatcher	*Myiarchus crinitus*	42385	3-4 years after first thin	8.4m	20.6cm	90%	7.2m
Great-crested Flycatcher	*Myiarchus crinitus*	44299	5-6 years after first thin	13.2m	23.9cm	55%	12.4m
Great-crested Flycatcher	*Myiarchus crinitus*	44306	5-6 years after first thin	3.80m	17.0cm	65%	2.8m
Great-crested Flycatcher	*Myiarchus crinitus*	44306	5-6 years after first thin	13.94m	29.5cm	35%	11.15m
Brown-headed Nuthatch	*Sitta pusilla*	42682	1-2 years after second thin	7.35m	19.8cm	20%	4.3m
Great-crested Flycatcher	*Myiarchus crinitus*	44429	1-2 years after second thin	11.32m	39.6cm	15%	9.1m
Yellow-shafted Flicker	*Colaptes auratus*	42682	1-2 years after second thin	9.24m	28.6cm	0%	8.31m
Carolina Chickadee	*Parus carolinensis*	42154	3-4 years after second thin	13.12m	21.2cm	10%	8.23m
Great-crested Flycatcher	*Myiarchus crinitus*	42739	5-6 years after second thin	14.12m	33.6cm	20%	8.1m

Table 7. Results of Student t-tests for comparison of snag and vegetation variables between snags with used and unused cavities.

Variable	Mean value for snags with used cavities ± SD	Mean value for snags with unused cavities ± SD	t value	p value	N (w/used cavities, w/unused cavities)
Height	8.67 ± 4.49	7.53 ± 3.62	1.01	>0.05	12, 104
DBH	24.05 ± 7.38	21.54 ± 7.55	1.09	>0.05	12, 104
Total Limbs	8.58 ± 7.79	4.71 ± 6.50	1.91	>0.05	12, 104
Height to 1st limb	4.57 ± 3.38	3.35 ± 4.05	1.00	>0.05	12, 104
% bark remaining (dec.)	.39 ± .31	.38 ± .29	0.13	>0.05	12, 104
Stems/m^2	2.28 ± 2.03	1.66 ± 1.70	1.10	>0.05	11, 84
Mean Vegetation Height	2.12 ± 0.78	1.90 ± .62	1.05	>0.05	11, 84

Table 8. Mean values ± SD and total values for species richness and overall bird numbers detected among stand age classes.

Stand Age	Mean species richness ± SD	Total number of species observed	Mean number of detections/100m of transect ± SD	Total number of detections
Pre-thin	7.2 ± 1.3	15	4.3 ± 1.6	129
1-2yr/1st thin	9.8 ± 3.1	21	4.9 ± 0.9	147
3-4yr/1st thin	10.4 ± 2.9	21	4.0 ± 0.6	120
5-6yr/1st thin	8.4 ± 1.8	21	3.7 ± 0.7	110
1-2yr/2^{cd} thin	11.8 ± 1.8	29	4.8 ± 0.4	143
3-4yr/2^{cd} thin	9.2 ± 2.2	20	4.0 ± 0.2	120
5-6yr/2^{cd} thin	11.6 ± 2.6	27	4.6 ± 1.2	145

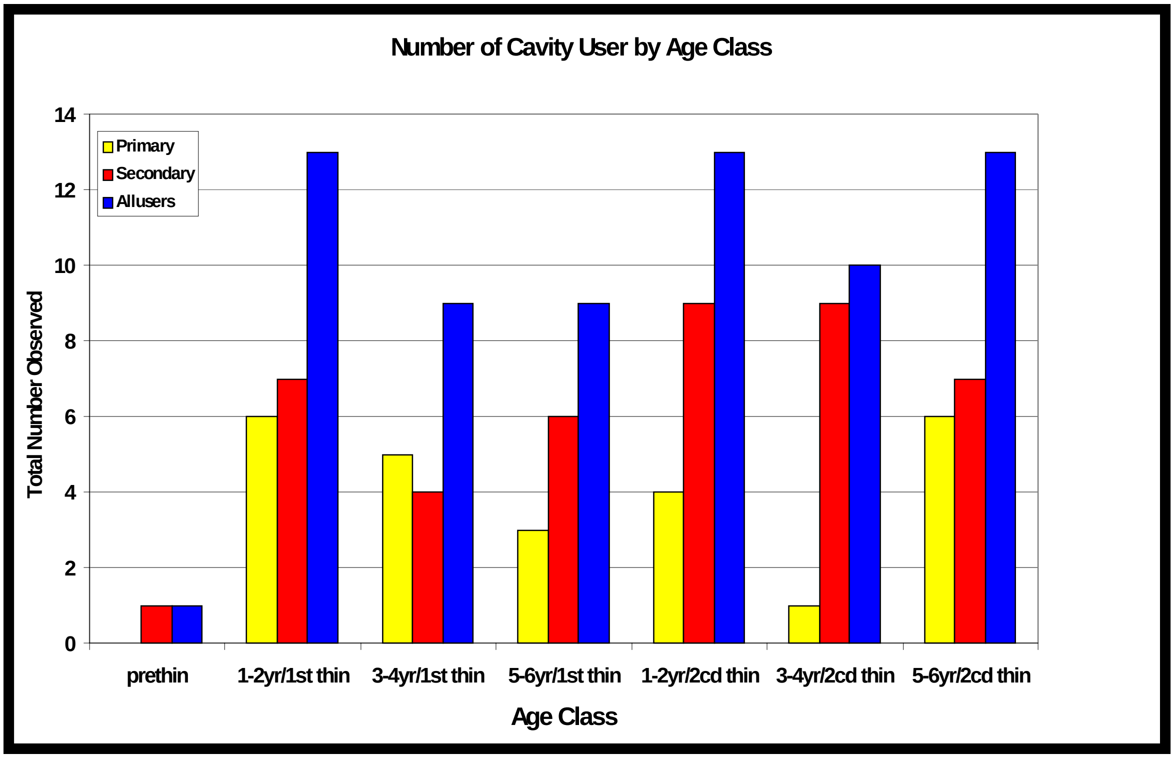

Figure 26. Total number of primary, secondary and combined cavity users detected within stand age classes.

DISCUSSION

The staggered management regime that creates a matrix of different aged stands also influences the recruitment and loss of snags within these stands. The number and characteristics of snags change throughout the management cycle, and are influenced by commercial thinning activities. Thinning activities appear to both create and contribute to the loss of older snags.

Within pre-thinned stands snag number were low. Snags that did occur within pre-thinned stands were generally short, had small DBH measurements, retained much bark and were not in advanced stages of decay. Snags with smaller DBH measurements decay at much greater rates than larger snags and thus have greater falling rates than larger snags (Raphael and Morrison, 1987). The detection of fewer snags in advanced stages of decay within this age class may be due to the rapid falling rate once the decay process begins.

A dramatic increase in the number of snags was observed immediately after the first commercial thin. It appears that unintentional mortality of young pines occurs during first thinning event. The number of snags/ha was greatest in theage class immediately after the first commercial thin (1-2 years after first thin). Snags within the 1-2 years after first thin age class had fairly small DBH measurements, high percentages of retained bark and had not undergone any substantial decay. As stands matured, through the age classes of 3-4 and 5-6 years after first thin, snag number declined slightly while the average DBH measurements and degree of decay increased. Reduction in snag density and increases in DBH measurements is attributed to snags within the smaller DBH classes decaying quicker and falling at greater rates than slightly larger snags.

After the second commercial thin marked decreases in snag density and increases in snag DBH were observed. Second thinning activities are likely to expedite the falling rate of smaller snags while creating new snags of greater size. As these stand matured the density of snags remained fairly constant with less variation than that observed in younger stands.

Cavity-bearing snags were nonexistent within pre-thinned stands. Snags present within this age class are too small and decay and fall at rates that make them unsuitable for cavity excavation. Cavity-bearing snags were most frequently detected in stands of 5-6 years after fist thin and older. A greater proportion of snags from these older age classes were of greater DBH and had undergone decay to a degree that made them ideal for cavity excavation. Although stands in the age classes of 1-2 and 3-4 years after first thin had a greater number of snags, these snags had not undergone a significant amount of decay to facilitate cavity excavation.

Within older stands a higher proportion of snags supported multiple cavities. The older, larger, and more decayed snags that occured at higher frequencies in older stands had greater numbers of cavities per snag. This is attributed to the fact that snags with greater DBHs have falling rates much lower that than smaller snags (Morrison and Raphael, 1993). Older snags are present for longer periods of time making them available for multiple excavations, and are of large enough size to support multiple excavations. Cavity use was lower than expected and may be due to missing early nesting attempts prior to the start of surveys. Cavity-bearing snags that were occupied consisted of a cross-section of available cavity bearing-snags. No clear preference was observed in cavity selection.

Results of bird surveys mirrored results of previous, more intensive surveys of the management stands conducted by Wilson and Watts (1999). Overall, bird numbers were dominated by shrub dependent species, species richness increased with age, and forest species are more frequently detected in older stands. Cavity users did not appear in appreciable numbers until after the first thinning event. An increase in the number of available snags, created by thinning practices, results in increased numbers of cavity users moving into thinned stands to utilize the newly available foraging, nesting and roosting sites. Wilson and Watts (1999) found that the presence of brown-headed nuthatches was associated with thinning events and snag presence, and were detected at greater frequencies in stands 1-2 years after thinning. While individual species were not detected in sufficient numbers during this study to permit species level analysis, cavity users as a group responded positively to thinning events.

Commercial thinning appears to be quite beneficial to the guild of birds that utilize snags and cavities. The unintentional creation of snags during thinning events provide foraging, roosting and nesting site for these species. The first commercial thin creates many smaller snags that decay quickly and have high falling rates. The second commercial thin appears to contribute to the decrease in total number of snags but the remaining snags and the new snags created are of larger DBH classes and have lower falling rates. These larger snags are available for longer periods of time and are more likely to have one or more cavities.

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LITERATURE CITED

Emlen, J.T. 1971. Population densities of birds derived from transect counts. Auk 88: 323-342.

Gunn, J. S. and J. M. Hagan. 2000. Woodpecker abundance and tree use in uneven-aged managed, and unmanaged, forest in northern Maine. Forest Ecology and Management. 126:1-12.

Morrison, M. L. and M. G. Raphael. 1993. Modeling the dynamics of snags. Ecological Applications. 3(2):322-330.

Raphael, M. G. and M. L. Morrison. 1987. Decay and dynamics of Snags in the Sierra Nevada, California. Forest Sciece. 33(3):774-783.

Raphael, M. G. and M. White. 1984. Use of snags by cavity-nesting birds in the Sierra Nevada. Wildlife Monographs. 86:1-66.

Wilson, M. D. and B. D. Watts. 1999. Breeding bird communities of a managed forest landscape in coastal North Carolina. Unpublished final report submitted to Weyerhaeuser Company. Center for Conservation Biology, College of William and Mary. Williamsburg, Virginia. 86pp.

Appendix I. List of species detected during transect counts , with alpha code, scientific name , and migration mode.

Common Name	Code	Scientific Name	Migration Mode
Northern Bobwhite	NOBO	*Colinus virginianus*	Resident
Mourning Dove	MODO	*Zenaida macroura*	Temperate migrant
Turkey Vulture	TUVU	*Cathartes aura*	Temperate migrant
Red-shouldered Hawk	RSHA	*Buteo lineatus*	Temperate migrant
Barred Owl	BDOW	*Strix varia*	Resident
Hairy Woodpecker	HAWO	*Picoides villosus*	Resident
Downy Woodpecker	DOWO	*Picoides pubescens*	Resident
Red-Bellied Woodpecker	RBWO	*Melanerpes carolinus*	Resident
Northern Flicker	YSFL	*Colaptes auratus*	Temperate migrant
Great-crested Flycatcher	GCFL	*Myiarchus crinitus*	Neotropical migrant
Eastern Wood-pewee	EAWP	*Contopus virens*	Neotropical migrant
Acadian Flycatcher	ACFL	*Empidonax virescens*	Neotropical migrant
American Crow	AMCR	*Corvus brachyrhynchos*	Resident
American Goldfinch	AMGO	*Carduelis tristis*	Temperate migrant
Eastern Towhee	EATO	*Pipilo erythrophthalmus*	Temperate migrant
Northern Cardinal	NOCA	*Cardinalis cardinalis*	Resident
Summer Tanager	SUTA	*Piranga rubra*	Neotropical migrant
Red-eyed Vireo	REVI	*Vireo olivaceus*	Neotropical migrant
White-eyed Vireo	WEVI	*Vireo griseus*	Neotropical migrant
Black-and-white Warbler	BAWW	*Mniotilta varia*	Neotropical migrant
Worm-eating Warbler	WEWA	*Helminotheros vermivora*	Neotropical migrant
Yellow-throated Warbler	YTWA	*Dendroica dominica*	Neotropical migrant
Prairie Warbler	PRAW	*Dendroica discolor*	Neotropical migrant
Pine Warbler	PIWA	*Dendroica pinus*	Neotropical migrant
Ovenbird	OVEN	*Seiurus aurocapillus*	Neotropical migrant
Louisiana Waterthrush	LOWA	*Seiurus motacilla*	Neotropical migrant
Common Yellowthroat	COYE	*Geothlypis trichas*	Neotropical migrant
Yellow-breasted Chat	YBCH	*Ictera virens*	Neotropical migrant
Hooded Warbler	HOWA	*Wilsonia citrina*	Neotropical migrant
Gray Catbird	GRCA	*Dumetella carolinensis*	Neotropical migrant
Carolina Wren	CARW	*Thryothorus ludovicianus*	Resident
Brown-headed Nuthatch	BHNU	*Sitta pusilla*	Resident
Eastern Tufted Titmouse	ETTI	*Baeolophus bicolor*	Resident
Carolina Chickadee	CACH	*Poecile carolinensis*	Resident
Blue-gray Gnatcatcher	BGGN	*Polioptila caerulea*	Neotropical migrant
Wood Thrush	WOTH	*Hylocichla mustelina*	Neotropical migrant

Appendix II. Bird species and total number of detection for both transect counts within each study stand.

Stand	NOBO	MODO	TUVU	RSHA	BDOW	HAWO	DOWO	RBWO
42003	-	1	-	-	-	-	-	-
42009	-	2	-	-	-	-	-	-
42015	-	3	-	-	-	-	-	-
42036	1	-	-	-	-	-	-	-
42154	1	-	-	-	-	-	-	-
42155	1	-	-	-	-	-	-	-
42206	-	-	-	-	-	-	-	-
42385	2	-	-	-	-	1	-	-
42402	2	-	-	-	-	-	-	-
42406	-	1	-	-	-	3	-	-
42430	2	-	1	-	-	-	-	-
42444	-	-	-	-	-	-	-	-
42462	-	-	-	-	-	1	-	-
42463	-	1	1	-	-	-	-	-
42469	-	1	-	-	-	-	-	-
42470	-	-	-	-	-	1	-	-
42472	-	1	-	-	-	-	-	-
42607	1	1	-	-	-	-	-	-
42682	-	2	-	-	-	-	-	-
42739	-	2	-	-	-	-	1	-
42792	-	2	-	-	-	-	-	-
44026	-	1	-	-	-	-	-	-
44298	-	-	-	-	-	-	1	-
44299	-	-	-	1	2	-	-	-
44306	1	1	-	-	-	1	-	-
44406	1	2	-	-	-	1	-	-
44429	1	-	-	-	-	-	1	-
44621	-	-	-	-	-	-	-	-
44715	-	-	-	-	-	-	-	-
44830	2	-	-	-	-	1	-	-
44931	2	-	-	-	-	-	4	-
44990	2	-	-	-	-	-	-	-
45071	4	-	-	-	-	-	-	1
45153	-	-	-	-	-	-	-	-
45212	1	2	-	-	-	-	-	-
Total	24	23	2	1	2	9	7	1

Appendix II (continued). Bird species and total number of detection for both transect counts within each study stand.

Stand	YSFL	GCFL	EAWP	ACFL	AMCR	AMGO	EATO	NOCA
42003	1	-	1	-	1	-	7	-
42009	-	-	1	-	-	-	5	-
42015	-	-	2	-	-	-	2	-
42036	-	-	-	-	1	-	12	-
42154	-	-	-	-	-	-	2	-
42155	-	-	-	-	1	-	8	-
42206	-	-	-	-	-	-	3	-
42385	-	-	-	-	1	-	1	1
42402	-	-	-	-	-	-	7	1
42406	-	-	1	1	-	-	3	-
42430	-	-	-	-	1	-	7	-
42444	-	-	-	3	-	-	4	-
42462	-	2	1	-	-	-	3	-
42463	-	-	1	-	-	-	3	-
42469	-	-	1	-	-	-	3	1
42470	-	-	-	-	-	-	8	1
42472	-	1	-	-	-	-	3	-
42607	-	-	-	-	1	-	5	-
42682	-	1	-	-	-	-	5	-
42739	-	-	-	-	-	-	5	1
42792	-	-	-	-	-	-	2	-
44026	-	-	-	-	-	-	3	-
44298	-	-	-	-	-	-	3	-
44299	-	-	-	-	-	-	9	-
44306	-	-	-	-	-	-	1	-
44406	-	-	-	-	-	-	1	-
44429	-	-	1	-	-	-	9	-
44621	-	-	1	-	-	-	2	-
44715	-	-	-	-	-	-	2	-
44830	-	-	-	-	-	-	6	-
44931	-	-	-	-	1	-	10	1
44990	-	-	-	-	1	-	4	-
45071	-	-	1	-	2	1	6	3
45153	-	-	-	-	-	-	11	-
45212	1	-	-	-	2	2	4	-
Total	2	4	11	4	12	3	169	9

Appendix II (continued). Bird species and total number of detection for both transect counts within each study stand.

Stand	SUTA	REVI	WEVI	BAWW	WEWA	YTWA	PRAW	PIWA
42003	-	-	2	-	-	-	-	-
42009	-	-	-	-	-	4	2	-
42015	-	-	4	1	-	-	-	-
42036	-	-	2	-	-	-	-	-
42154	-	-	2	3	-	-	1	-
42155	-	-	2	2	-	-	1	-
42206	-	-	8	-	-	-	2	-
42385	1	-	2	-	-	-	2	-
42402	-	-	5	-	-	-	-	-
42406	-	1	2	1	-	-	1	-
42430	-	-	5	-	-	-	-	-
42444	-	-	3	1	-	-	-	-
42462	-	1	4	2	-	-	2	1
42463	-	-	4	1	-	-	-	-
42469	-	-	1	-	-	-	-	-
42470	-	-	5	-	-	-	-	-
42472	-	-	5	1	-	-	-	-
42607	-	-	2	-	-	-	1	-
42682	1	1	2	2	-	-	-	2
42739	-	-	2	1	-	-	3	-
42792	-	-	3	-	-	-	-	-
44026	-	-	3	-	-	-	-	-
44298	2	-	5	-	-	-	3	-
44299	-	-	-	-	-	-	-	-
44306	-	-	4	-	-	-	2	-
44406	-	-	3	-	-	-	2	-
44429	2	-	2	-	-	-	-	1
44621	-	-	1	-	1	1	-	1
44715	-	-	2	-	-	-	4	-
44830	-	-	2	-	-	-	-	-
44931	-	-	-	-	-	-	-	-
44990	-	-	-	-	-	-	-	-
45071	-	-	2	-	-	-	-	1
45153	1	1	3	-	-	-	2	-
45212	-	-	2	1	-	-	-	-
Total	7	4	94	16	1	5	28	6

Appendix II (continued). Bird species and total number of detection for both transect counts within each study stand.

Stand	OVEN	LOWA	COYE	YBCH	HOWA	GRCA	CAWR	BHNH
42003	-	-	8	-	-	2	-	1
42009	-	-	7	-	-	-	-	-
42015	1	1	4	-	1	2	-	-
42036	-	-	9	1	-	2	-	-
42154	3	-	6	-	-	3	-	-
42155	2	-	8	-	-	1	-	2
42206	3	-	8	-	-	-	-	-
42385	1	-	6	-	-	2	-	-
42402	-	-	9	-	-	2	-	-
42406	1	-	2	1	1	2	-	-
42430	-	-	10	-	-	2	-	-
42444	-	-	5	-	-	2	-	-
42462	1	-	5	-	1	1	-	-
42463	2	-	9	-	-	8	-	-
42469	1	-	8	-	1	5	1	-
42470	1	-	9	1	-	1	-	-
42472	-	-	6	-	-	4	-	1
42607	-	-	6	-	-	-	-	-
42682	-	1	5	-	-	4	-	-
42739	-	-	5	-	-	6	-	1
42792	-	-	5	-	-	3	-	-
44026	-	-	2	-	1	5	-	1
44298	1	-	4	-	-	-	-	-
44299	-	-	9	-	-	6	-	-
44306	-	-	5	-	1	-	-	-
44406	1	-	5	-	-	1	-	-
44429	-	-	3	-	-	-	1	-
44621	6	-	5	-	-	-	-	-
44715	-	-	5	-	-	7	-	-
44830	-	-	5	1	-	1	1	-
44931	-	-	9	-	-	1	-	-
44990	3	-	6	-	-	-	-	-
45071	-	-	9	-	-	4	-	-
45153	2	-	16	-	-	4	-	-
45212	-	-	10	-	-	1	-	-
Total	29	2	233	4	6	82	3	6

Appendix II (continued). Bird species and total number of detection for both transect counts within each study stand.

Stand	ETTI	CACH	BGGN	WOTH	Total
42003	-	1	4	-	29
42009	-	1	-	1	23
42015	-	-	-	2	23
42036	-	-	1	1	30
42154	1	-	1	-	23
42155	-	1	2	-	31
42206	-	2	-	-	26
42385	-	2	3	1	26
42402	-	-	-	-	26
42406	-	-	2	2	25
42430	-	-	-	-	28
42444	-	4	1	-	23
42462	-	2	3	3	33
42463	-	-	2	-	32
42469	-	-	1	1	26
42470	-	-	-	1	28
42472	1	-	1	1	25
42607	1	-	1	-	19
42682	2	-	2	1	31
42739	2	-	5	-	34
42792	-	-	1	-	16
44026	-	-	1	1	18
44298	2	-	-	-	21
44299	-	-	2	-	29
44306	1	1	-	1	19
44406	-	-	2	-	19
44429	1	4	2	-	28
44621	1	-	2	-	21
44715	-	-	2	-	22
44830	1	-	2	2	24
44931	-	-	-	-	28
44990	-	4	1	-	21
45071	-	-	1	-	35
45153	-	-	-	-	40
45212	2	1	3	1	33
Total	15	23	48	19	914